METAL PROGRESS

NOVEMBER 1952

Surface

Peak Industrial Heating Efficiency...

70 TYPES 700 SIZES TO MEET ALL INDUSTRIAL NEEDS!

Regardless... of whether your industrial heating requirements involve solids . . . liquids . . . air there is a 'Surface' Burner to master the job with peak efficiency and economy. 'Surface' Burners, the product of 42 years of "know how" give you automatic proportioning through a wide range of turndown . . . fast and complete combustion of the fuel-air mixture . . . flexibility in their process and production application. These, plus 70 types and 700 sizes suggest a standardization program on 'Surface' Burners in the best interests of top production returns. Let us help you with your future burner planning.

WRITE FOR VALUABLE BOOKLET

SURFACE COMBUSTION Corporation

TOLEDO 1, OHIO

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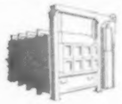
'Kathabar'

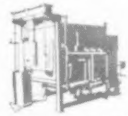
Janitrol

STANDARD RATED FURNACES AND EQUIPMENT

FACTORY ASSEMBLED . . . DELIVERED AND INSTALLED IN MINIMUM TIME



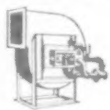
Oven Furnaces • Direct-fired. For heat treating all types of steels, as well as copper, brass, and aluminum.



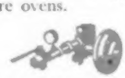
Atmosphere Furnaces • Indirect heated. For heat treatment of metals where surface protection and dimensional stability are required. Furnished also in special types.

Pot Furnaces • For heating all types of metals in liquid baths. Available with either circular or rectangular pots.

Convection Furnaces • Designed for all low temperature heat treating operations on ferrous and non-ferrous alloys. Horizontal and vertical types.



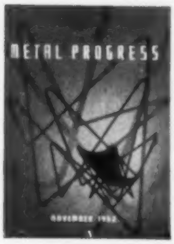
Air Heaters • Direct type. For convection heating of all types of low temperature ovens.



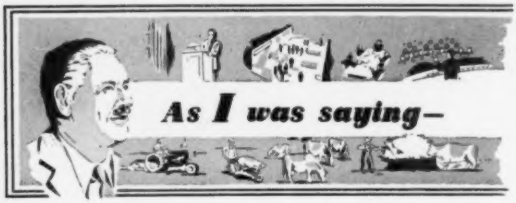
Burners • Over 70 types and 700 sizes for all heating operations. Low pressure, high pressure, and atmosphere gas systems.

Atmosphere Generators
Forge Furnaces
Metal Melting Furnaces

IN THIS ISSUE



A modern metal chair caught the eye of this month's cover artist, Frank Saso, and won him second prize in the annual cover competition at Cleveland School of Art



THE A.S.M.-N.S.T.A. search for the Future Scientists of America is beginning to bear fruit.

The A.S.M.'s first contact with the National Science Teachers Association came three years ago when an appropriate method was being sought for distributing the 100-page booklet on "Your Career in Metallurgy", prepared by our capable author, Dr. John W. W. Sullivan (formerly with the Cleveland *Plain Dealer*, now staff member of A.I.S.I.). The booklet was successfully distributed to 8000 secondary-school members of the National Science Teachers Association in its well-known "Science Packet".

The more the A.S.M.'s chapters and committees studied the pressing problems of encouraging and increasing the enrollment in engineering schools, the more important became the role of the science teachers. A survey of a large metropolitan school system showed that only 20% of the high school graduates had the necessary science credits to meet entrance requirements for engineering schools. If one waits until the student is a senior to bring engineering to his attention, a science deficiency exists in four out of five cases, and it's too late to correct it.

So the A.S.M., while concentrating its efforts through the chapters to interest students in engineering, has undertaken a long-range program to create a greater interest in science in the junior and senior high schools by sponsoring, through the N.S.T.A., the "A.S.M. Science Achievement Awards Program" for students, teachers and schools.

This action program, established by A.S.M. in cooperation with N.S.T.A., is designed to help assure a strong and free America, with strong, thorough, adequate scientists for research, technology, teaching and engineering. It is designed to stimulate interest and encourage both individual and group experimentation and projects in science by students in junior and senior high schools; to encourage higher regard for good science teaching by providing awards to the schools as well as the students; and to recognize science teachers who develop effective techniques for stimulating interest and activity in science among their students in grades 7 through 12.

The awards are open to all students in public, private and parochial schools in the United States and Canada. Students in grades 7 to 10 may feature any activity in any science; 11th and 12th-grade students must confine their projects to metals and engineering. The program provides 40 student awards, 20 school awards and 20 teacher awards. *Metals Review* for October reports the successful trial run of the first award program for 1952. John Bennett of the Bureau of Standards, a past chairman of the Washington Chapter, is A.S.M.'s capable representative on the Awards Committee.

The 1952 awards will be presented to pupils and schools by representatives of the A.S.M. and the N.S.T.A. during American Education Week, Nov. 9 to 15.

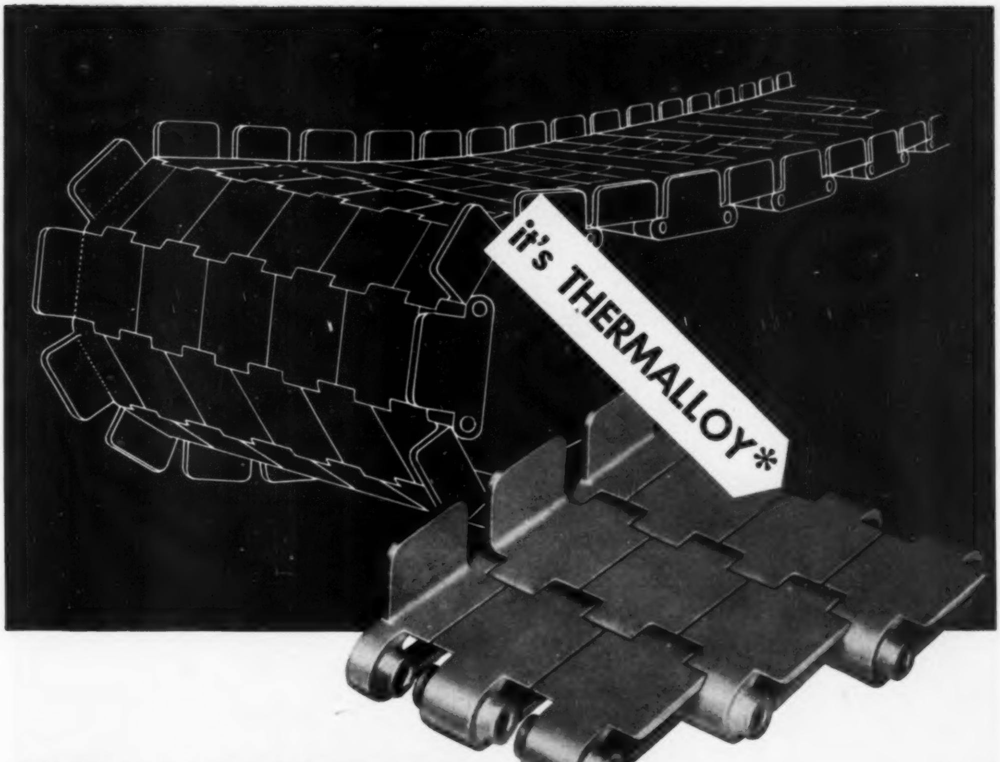
A.S.M. is proud to be sponsoring this long-range program. As the engineering society of the metals industry, we accept our share of the responsibility for encouraging young students to undertake careers in engineering, knowing full well that nearly 50% of all engineers will find their life's work in the metal producing and fabricating industries.

And so the Science Awards are another red feather for a red-blooded A.S.M.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS



NEW DESIGN# means

GREATER STRENGTH · INCREASED LOAD CAPACITY

Note the "staggered" link arrangement in the new Thermalloy conveyor belt section illustrated above. It offers you special advantages in heat-treat applications.

First—this design of link eliminates "crank-shafting".

Second—the new design can carry a considerably heavier load, without increasing the amount of alloy used.

Third—the use of shorter, free-floating, "cast-in" pins, instead of large and rigid continuous wrought pins used in conventional designs, reduces bending stresses under heavy loads.

For full information on this improved Thermalloy conveyor design, contact your nearest Electro-Alloys representative. Or write Electro-Alloys Division, 2105 Taylor Street, Elyria, Ohio.

Pat. Applied For   *T.M. Registered, U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
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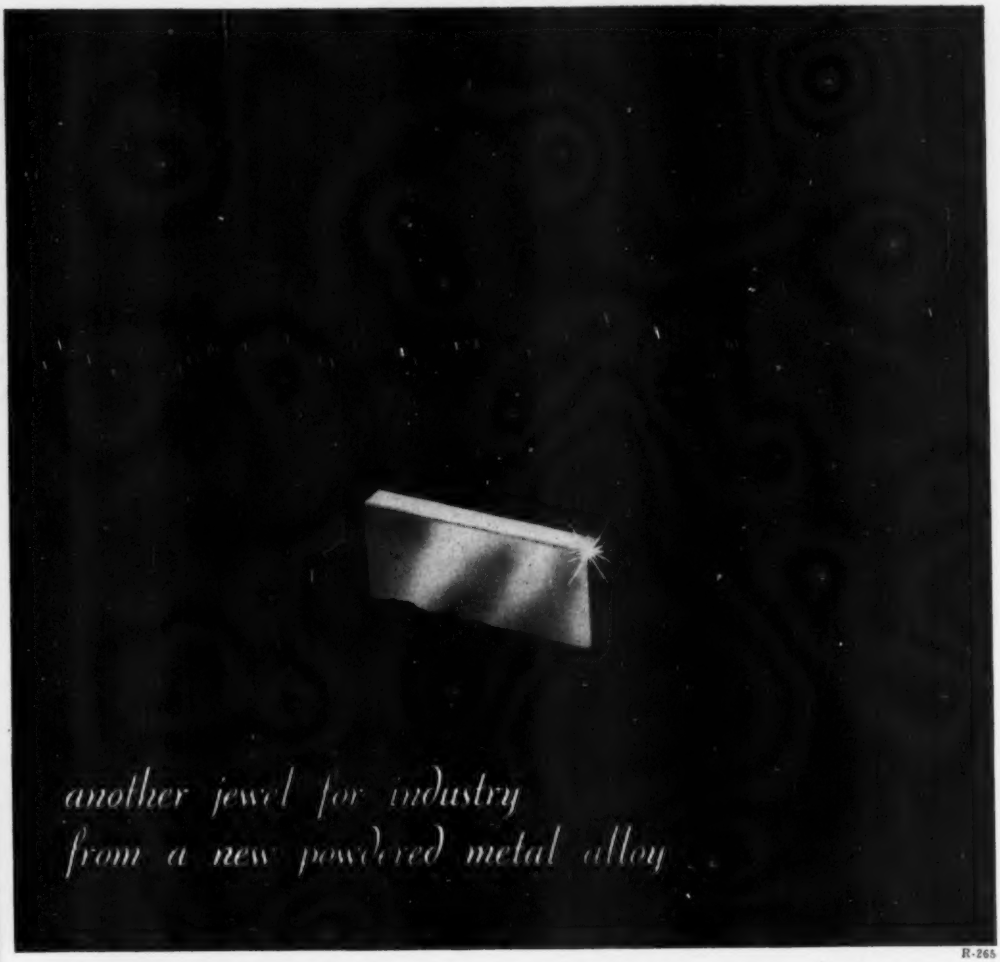
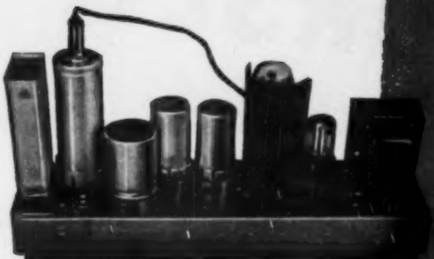

another jewel for industry
from a new powdered metal alloy

A lot of Engineering for an Amplifier, but...



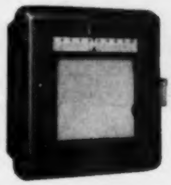
Good engineering shows in this Amplifier's wide range of sensitivities, and of impedances, thorough filtering and plug-in connection to the rest of the Speedomax instrument.

Good engineering shows in this Converter's phenomenally low noise level and in its long-lived performance.

Good engineering shows in this Slide-wire's non-inductive winding and in absence of any flexible leads which might form inductive loops.

Good engineering shows in this balancing motor's small size, and in its torque ample to operate accessory control and signalling fitments.

it helps Speedomax to fit your ideas!



• Your needs and ideas put this electronic "tool" to work on an amazing variety of jobs. Controlling furnaces and peering into atoms; counting bottles and spying on the weather; taking the "shine" out of rayon or putting it on hardware, to name six out of thousands of uses. For, in general, if you can feed Speedomax a tiny electrical signal, representing the condition you wish to measure, the instrument will not only put "calipers" on it, but will amplify it enormously to direct anything that can be directed through electrical or pneumatic means.

The Speedomax way of handling this job provides particularly accurate results and an especially good fit in meeting your individual ideas. For instance, there's the matter of receiving the signal in a way suited to its size—or, more usually, to its smallness.

We have no less than twenty-three carefully-engineered Speedomax Amplifiers covering a wide range of sensitivity and impedance levels. One Amplifier in the series enables the Speedomax to respond to a signal of only 10^{-16} watt—one ten-billionth of a microwatt. No other recorder amplifier comes within 3 magnitudes of this figure. Such sensitivity means corresponding accuracy in detecting the tiny unbalance—called "error" by circuit engineers—which actuates the rebalance system.

In terms of power, all 23 Amplifiers deliver the same—5 or 6 watts. This is from 2 to 4 times the output of other recorder amplifiers; permits a more powerful balancing motor. And the Amplifier-Motor team provides an especially high torque gradient just where it's needed—centering around the balance point—for prompt, positive balancing and easy, effortless operation of a "heavy" load of control or signal devices in the motor shaft.

The Speedomax story for industry is told in Catalog ND46(1); for Research, in Tech. Pub. ND46(1). We will send either on request; address our nearest office or 4927 Stenton Ave., Phila. 44, Pa.

CAREER OPPORTUNITIES AT L&N

Expansion program of this long-established firm has many features to attract outstanding recent graduates in engineering and science. Opportunities are in sales field engineering, product and application engineering, research, advertising, market development. Widely-respected policies assure recognition of progress and achievement. Address Personnel Manager for preliminary interview at nearest of 17 L&N offices.

LEEDS NORTHRUP

Instruments automatic controls • furnaces

Jrl. Ad. ND46(7)

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SAVE YOURSELF
from costly, excessive wear
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NAVY
63
Piasecki Helicopter Corporation
Morton, Pennsylvania
Problem:
To find a material that withstands severe shock loads, high operating speeds, corrosive action of the elements and, at the same time, provides good bearing qualities when needed for such parts as:
Dowel-Rotor Blade Leading Edge, Bushing-Trim Mechanism, Bearing-Collective Pitch Lever Flange, Bearing-Collective Pitch Lever Grip, Bearing-Collective Pitch Lever Throttle, Bushing Collective Pitch Friction Slide, Bushing-Trim Control Actuator Support Collar, Bushing-Flexible Shaft Coupling, Support Assemblies — Power Plant Engine Controls — Fuel Shut-Off, Cone-Inner Fan Hub Drive System, Cone-Outer Fan Hub Drive System, Collar-Fan Hub-Drive System, Swivel Details — Pilot's Controller Arm on the Auto Pilot; Bushing-Sway Structure Fitting, Upper Attachment; Washer-Rescue Hatch Actuator.
Solution:
AMPCO METAL
Results:
The performance of Piasecki Helicopters under all kinds of conditions is proof of the life-saving dependability of these units. This ability to "take it" has established Piasecki as a leader in the development of transport helicopters.
IT'S PRODUCTION-WISE TO AMPCO-IZE!
Tandem-rotored six-place craft with large rescue hatch. Its mission—search and rescue utility transport.
71
NAVY

Rear cone for airplane propeller — Centrifugally-cast.

Gear for metal spray gun — Extruded-rod.

with AMPCO* METAL

Here are the properties of Ampco Metal that appeal to designers and plant-operating men — properties that increase the service life of machines and reduce upkeep costs:

High compressive strength — Ampco Metal doesn't squash out. . . . High resistance to corrosion, erosion and abrasion. . . . High impact and fatigue values. . . . Excellent bearing qualities.

Because Ampco Metal has this ability to stand up under the severest kind of service, leading companies, like Piasecki Helicopter Corporation, use these outstanding aluminum bronze alloys to provide an extra margin of safety and dependability.

If you have a wear problem in either product or plant, investigate the cost-saving properties of Ampco Metal. You can get it in practically any form you need — sheet, plate, sand and centrifugal castings, forgings, bars, tubes, welding wire and electrodes. For further information consult your nearest Ampco field engineer or send this coupon.

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Bushings — Centrifugally-cast Ampco Grade 18 standard bars.

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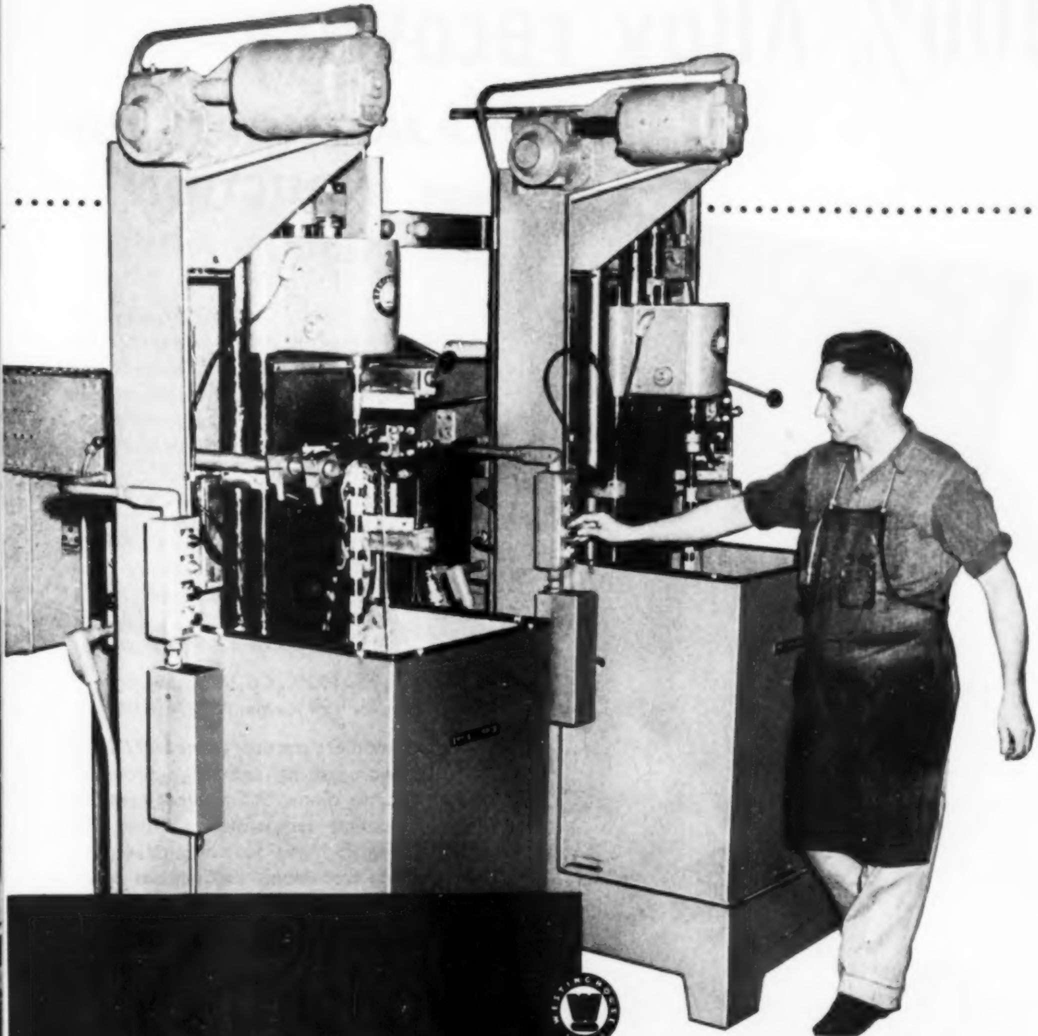

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J-02252

Two booklets help you solve induction heating problems.

For information on Westinghouse Induction Heating, send for either or both of these booklets:

B-4782 for details on heating, joining, and annealing, with numerous case histories.

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Westinghouse Electric Corporation,
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Baltimore 3, Maryland

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Company..........

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Ajax-Northrup furnaces are famous for their ability to give back what you put into them. They melt *any* metal with minimum losses, at high speeds, and with extremely accurate control of analysis and pouring temperatures.

For example, a foundry using these furnaces to melt stainless steel for corrosion and heat resistant castings reports the following figures on recovery of elements going into the make-up of 18-8 type alloys:

Ni: 100% Cr: 99% Mn: 90%
Si: 94% Mo: 95% Cb: 92%

Another Ajax user saves $60,000 a year just by reducing chromium losses alone. Still another controls pouring temperatures within 20 deg. F., turns out castings so perfect that repair welding has been eliminated.

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134

FOR HEATING AND MELTING

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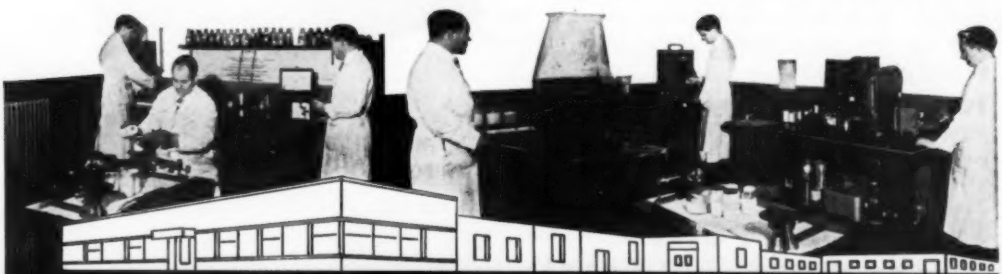

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Now Ready...

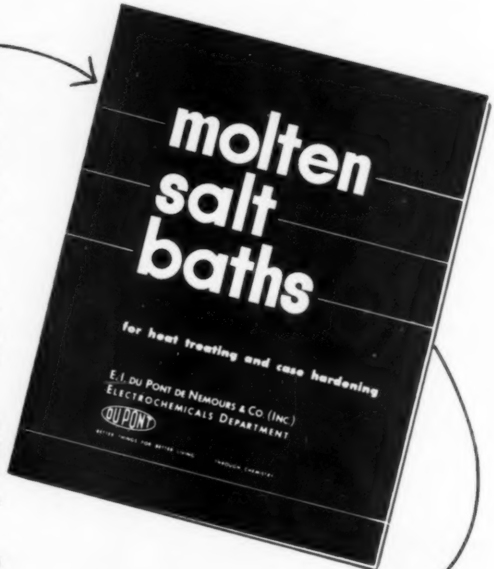
complete information on case hardening and heat treating salt baths

YOU'LL FIND complete descriptions of Du Pont Salt Baths for cyaniding, carburizing, heat treating and salt bath quenching . . . how the baths are prepared and controlled and what results can be produced. You'll also find detailed information on salt baths for such special applications as cyanide reheating and nitriding, hydride descaling and heat coloring.

YOU'LL SEE illustrations of the equipment used . . . tables of bath formulations and replenishment equivalents . . . and charts and photomicrographs showing the heat treating and case hardening properties of various S. A. E. steels.

YOU'LL LEARN how Du Pont molten salt baths can increase production capacity, shorten heat treating and case hardening cycles and save space . . . how they can help you produce a better, more uniform product at lower cost.

YOU'LL PROFIT by sending for this new 75-page manual today! It will serve as a valuable reference guide in metal treating operations of all types.



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Electrochemicals Department
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for METAL TREATING

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150th Anniversary

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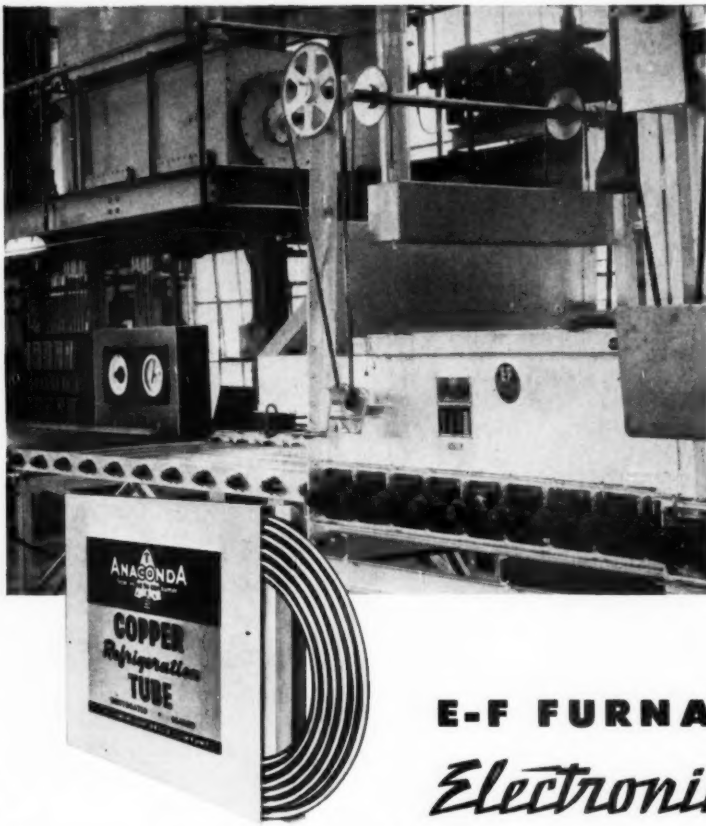

*"Anaconda" refrigeration tube is bright annealed in this Electric Furnace Co. continuous roller hearth furnace, equipped with **ElectroniK** temperature controllers.*

E-F FURNACE—*plus*
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teamed for precision annealing

Bright annealing of small-diameter copper refrigeration tube, at The American Brass Company's mill at Waterbury, Connecticut, calls for high precision and high production. Both these objectives are obtained by means of a continuous roller hearth furnace, made by The Electric Furnace Company, regulated by a pair of *ElectroniK* temperature controllers.

The furnace is the gas-fired, radiant tube type, and operates with a protective atmosphere. Gas input to its two zones is regulated by an *ElectroniK* indicating controller and a circular chart *ElectroniK* recording controller. These instruments respond quickly and accurately to every temperature change . . . hold specified temperatures hour after hour, week after week.

No matter what type of furnace . . . how close your temperature tolerances . . . you'll be sure of sensitive, precise performance when you specify *ElectroniK* instruments. The wide variety of sensing elements, instrument models, and types of control—both electric and pneumatic—covers every industrial application.

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BROWN INSTRUMENTS

First in Controls

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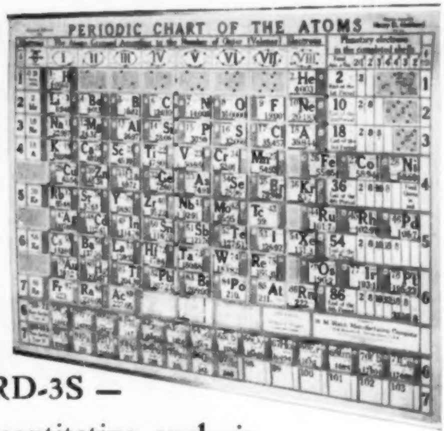
Write today for Catalog 51-1, "Furnace and Oven Controls."

Take a number — any atomic number from 22 to 97...



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There's no guesswork when you handle quantitative analyses with the GE XRD-3S x-ray spectrometer. Take any sample — you get a direct chart record of composition by element in the 22-97 range.

Accuracy is maintained over a wide range of concentration — from hundreths-of-a-percent to 100%. It's fast — only one to five minutes per element — and non-destructive.

Basis for this outstanding performance is GE's patented curved focusing mica crystal. Because it permits a high degree of resolution coupled with very high intensities, accuracy and speed exceed those possible with conventional flat crystals.

General Electric XRD-3S spectrometers are proving their value in all fields — chemical, petroleum, ceramic, mineral, metallurgical. "Metallurgical Applications of X-Ray Fluorescent Analysis" points out how Allegheny Ludlum Steel Corporation applies this method. For a copy and descriptive literature, write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin. Request Pub. AS-11.

You can put your confidence in —

GENERAL ELECTRIC

ON MINNEAPOLIS-MOLINE'S UNI-HARVESTOR...

SHAFT SIZE REDUCED from 1½" to 1¼"

BY USING **HIGH-STRENGTH**

GROUND AND POLISHED

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The UNI-HARVESTOR is really different. It harvests grains, beans, and all seeds—it picks and husks corn, and bales or chops hay. Ground and Polished STRESSPROOF is specified for the cylinder shaft.

● In designing this Cylinder Shaft, Minneapolis-Moline engineers specified Ground and Polished STRESSPROOF to meet the increasingly severe operating conditions to which this equipment is subjected. The alternative would have been lower strength shafting with an increase in size. The larger shaft would have been 44% heavier, and bearings and gears would have had to be redesigned. Ground and Polished STRESSPROOF proved to be stronger, had better fatigue properties, and machined better. It eliminated heat-treating and straightening operations, and the size accuracy provided a correct bearing mounting.

STRESSPROOF makes a better part at lower cost.

STRESSPROOF is a severely cold-worked, furnace-treated, carbon steel bar with a unique combination of four qualities in the bar: (1) Strength, (2) Wearability, (3) Machinability, and (4) Minimum Warpage. Yet it costs less than other quality cold-finished steel bars. Available in cold-drawn or ground and polished finish.

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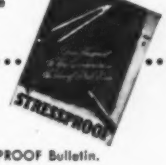

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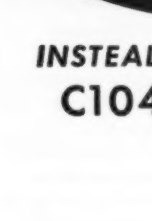


La Salle STEEL CO.

... the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Bars in America.

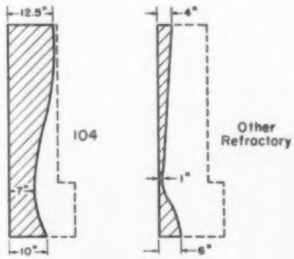
Engineering Digest

OF NEW PRODUCTS

POLISHING HEAD: The new Murray-Way head was developed especially for deburring of turbine disk-slots and incorporates universal-positioning features. The head may be used with either wheels or buffs

and is compact in design, making its use in groupings practical with a minimum of floor area. Two, three or four heads are used. Heads may be dropped or added easily.
For further information circle #1372 on literature request card on p. 32B

OPENHEARTH REFRACTORY: Corhart 104 is a new magnesite-chrome refractory, electrically melted



After 124 Heats

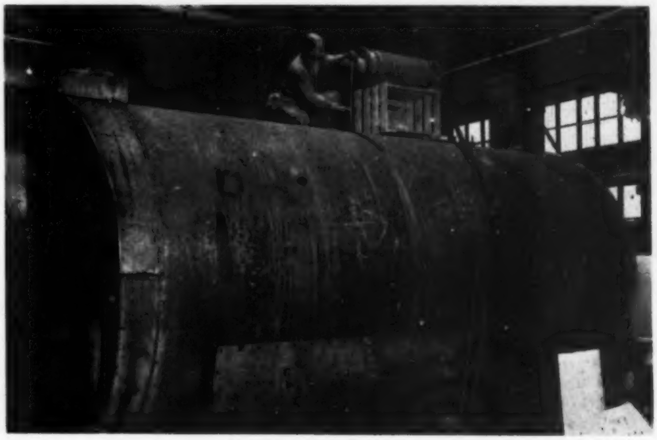
and cast for use in metallurgical processes. During a test in an open-hearth steel melting furnace, Corhart 104 remained in the test for 229 heats. The comparison refractory, a top-quality basic material, was replaced once and patched twice in the same period. The accompanying illustration shows cross sections after 124 heats, at which point the other refractory failed. Additional tests in furnaces of other companies gave similar results.
For further information circle #1373 on literature request card on p. 32B

NICKEL ALLOY STRIP: Ultra-thin nickel alloy strip, rolled to precision tolerances, is now available from American Silver Co. in any quantity from one pound up. Gages down to 0.0005 in. are rolled, with tolerances as close as 0.0001 in.
For further information circle #1374 on literature request card on p. 32B

SHELL MOLDING EQUIPMENT: Powdered Metal Products Corp. has announced that equipment and procedures developed by G. L. Bachner for shell molding will be made available to the foundry industry. The main purpose of the development work was to find practical, economical production processes and equipment for applying the shell molding process. After pilot runs using various methods, a completely automatic machine for turning out approximately 20 complete shells from a single set of dies every hour was developed by Mr. Bachner. This machine performs all steps of the shell molding operation, delivering finished shells ready for pouring or storage. The machine is designed to accommodate dies up to 12 by 18 in. After dies have been inserted, the sequence of operations performed by the machine is as follows: (1) Heat die by means of electrical elements inserted in the die shoe, (2) dump mixture of sand and resin on heated die from machine hopper, (3) cure contact surface of the shell by holding the mix in contact

RADIOGRAPHY: A new portable X-ray unit, displayed for the first time during the National Metal Exposition in Philadelphia by the General Electric Co., X-Ray Dept., is capable of radiographing anything from light alloys to 3½ in. of steel. It operates at from 75 to 250 kvp. Less than 15 in. in diameter and 44 in. long, the unit is 56% smaller in size than the conventional 250,000-volt X-ray machine. The weight of the new unit is only 150 lb., as compared to 1150 lb. for the conventional apparatus. As a result, the X-ray unit can be brought to the product, instead of bringing the product to the X-ray machine. In appearance it resembles an industrial tank-type vacuum cleaner. Its use on light metals is possible, operating at lower voltages, because of the X-ray tube's beryllium window which allows the less-penetrating rays to escape from the tube, instead of being absorbed as they are by other types of windows.

Secret of the size and weight reduction is the use of a high frequency, resonant transformer. This eliminates the need for the closed iron core ordinarily used in transformers for industrial X-ray units of this voltage. Another contributing factor is the use of gas insulation instead of heavy oil. Known by the trade name Resotron 250 (resonant transformer rated at 250 kvp.), the unit is operable throughout the 75 to 250 kv. range from either a 220 or 440 v., 3-phase, 60-cycle supply and from 2 to 10 ma. in tube current. It can be operated in temperatures of from 35° below zero to 100° above zero, and in humidities up to 100%.
For further information circle #1375 on literature request card on p. 32B



FROM DINNER BELLS

TO MORTAR SHELLS

you can test practically anything with a

RIEHLE

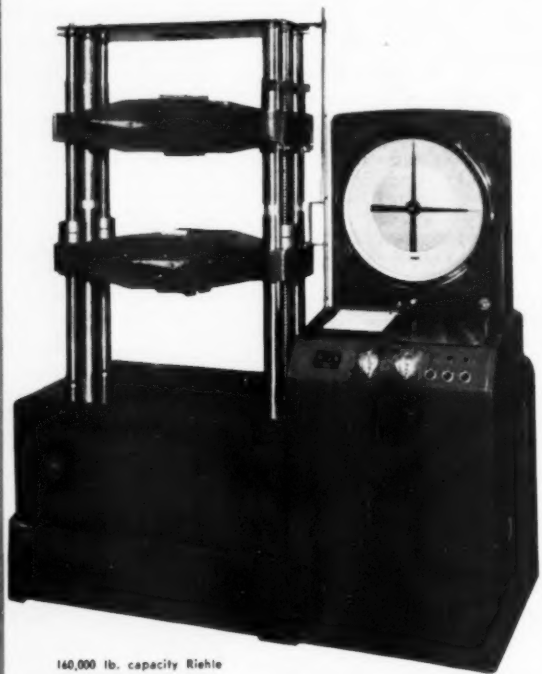
UNIVERSAL TESTING MACHINE

On the same Riehle machine, you can test small specimens with a relatively low-rupture-point or large, high-yield-point specimens. That's because every Riehle Pendomatic Universal Testing Machine has 5 scale ranges — the equivalent of 5 testing machines in one.

You just select the most logical scale range, turn the selector knob and conduct your test. No accessories are needed. Guaranteed accuracy is within ½ of 1%.

Hydraulic and Screw Power Types

Riehle Universal Testing Machines are built both with hydraulic loading unit and with screw power loading unit. Each type is available in a variety of sizes, with capacities up through 400,000 lbs. Ask your Riehle representative or write our factory for illustrated catalogs.



160,000 lb. capacity Riehle Screw Power Universal Testing Machine illustrated.

RIEHLE TESTING MACHINES

Division of AMERICAN MACHINE AND METALS, INC.

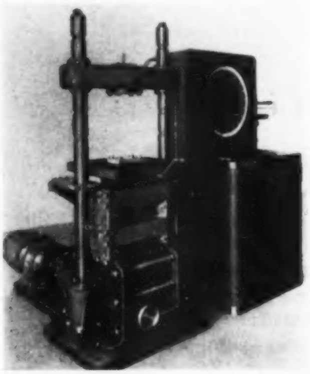
East Moline, Illinois

"ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS"

with the heated die for a precisely timed interval, (4) roll over to dump excess sand mixture back into the machine hopper, (5) oven-cure the shell to make it permanent, and (6) eject completed shell.
For further information circle #1376 on literature request card on p. 32B

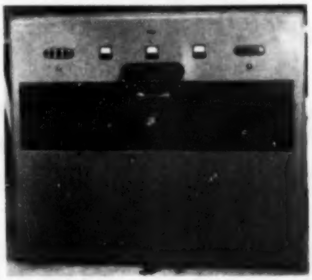
SHELL MOLDING: A new adhesive for bonding shell mold halves is offered by World Bestos. The adhesive can be applied closely to the casting cavities and, when heat cured, holds the mold evenly with great strength. The need for shot or silica sand backing of most molds is eliminated, solving one of the most critical materials handling problems in the entire shell molding process. The bonding adhesive, supplied either as a film or liquid, disappears in the shell reclaiming process, eliminating the problem of bolt or clamp removal from the molds.
For further information circle #1377 on literature request card on p. 32B

TESTING MACHINE: A new type of universal testing machine, incorporating an electric weighing system and electronically-controlled, motor-driven loading mechanism, is announced by Baldwin-Lima-Hamilton Corp. The



new Model FGT Baldwin-Emery SR-4 testing machine has a capacity of 50,000 lb. load and embraces the following characteristics: weighing and measuring tolerances of 0.2% of the scale reading, high-speed response of indicator or recorder to dynamic as well as static loads, extreme structural stiffness and lateral rigidity, standard loading speed of 0.025 to 9.0 in. per min., automatic loading control for maintaining constant load, constant strain, constant rate of loading, or constant strain rate, thus enabling determination of creep, rupture, and relaxation properties.
For further information circle #1378 on literature request card on p. 32B

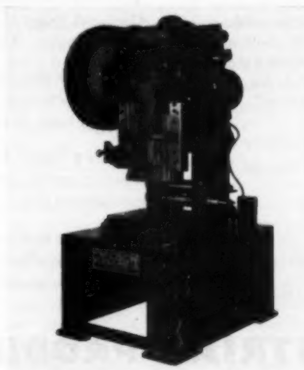
INDUCTION HEATER: Lindberg Engineering Co. has added a new 50-kw. unit to its line of high-frequency induction heating units. Built to provide 50 kw. at 400,000 cycles per sec. on a 100% duty cycle, the unit features a built-in closed water system



that circulates temperature-controlled water to the oscillator tube and tank coils. Water consumption averages 22.5 gpm. at full load. Input voltage is 230, 460 or 550, 3 phase, 60 cycle, 100 kva. max., 90% power factor.
For further information circle #1379 on literature request card on p. 32B

SILICON METAL: High-purity silicon powders specially processed to meet rigid chemical requirements for the manufacture of crystals for radar, video relay, and other microwave applications are now available from the Tungsten and Chemical Div. of Sylvania Electric Products Inc. The new powders have purities of 99.85% and 99.95%.
For further information circle #1380 on literature request card on p. 32B

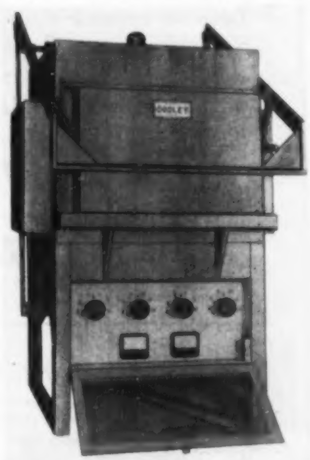
STAMPING PRESS: A new high speed automatic stamping press has been announced by Precision Welder & Flexopress Corp. In this press of 30-ton capacity, with feed rolls built



integral, both ram and connecting link are of high strength, light alloy material, approximately 35% the weight of the cast iron generally used. Another feature of this press is its wide versatility of feeding and stamping materials ranging from 0.002-in. aluminum foil to heavy metals within the range of its 30-ton capacity.
For further information circle #1381 on literature request card on p. 32B

SILVER BRAZING FLUX: A new flux G-B-99 provides exceptional ability to climb and spread over the entire joint area, is satisfactory for torch applications where heating cycles are short, and is active through a temperature range of 800 to 1350° F. G-B-99, made by Goldsmith Bros. Smelting & Refining Co., is completely dehydrated and is packaged as a dry flux. Water is added to make a creamy paste.
For further information circle #1382 on literature request card on p. 32B

HEAT TREATING FURNACES: Three models in a new line of electric high speed tool steel hardening furnaces have been announced by the Cooley Electric Mfg. Corp. Operating temperatures cover the range of 1650



to 2500° F. The following chamber sizes are available: 6¼ by 4 by 9 in.; 12 by 8 by 18 in.; and 12 by 8 by 24 in. Control of power is accomplished by use of multiple-tap transformers arranged for select voltages to be applied to the Globar elements located at the top and the bottom of the chamber.
For further information circle #1383 on literature request card on p. 32B

SCALE REMOVAL: Magnus Chemical Co. has carried out tests in its plant-scale laboratory which have resulted in a large reduction in the cost of descaling rings for 20-mm. shells

for a large producer of these parts. Formerly they had sent these rings out to a job shop for descaling and brightening, at a cost of about 0.4¢ per ring. The Magnus method now enables them to do the operation in their own shop at a cost of less than 0.01¢ per ring. Tests indicated that when Magnus D-Scale-RS was used in a tumbling barrel, results would be satisfactory without the use of stones or other abrasives. The cleaner is of the inhibited acid type, safe for use on copper alloys without danger of tarnishing or corroding.
For further information circle #1384 on literature request card on p. 32B.

GLOBAR FURNACE: Model FG-76 is the latest addition to the line of electric heat treating furnaces manufactured by the Pereny Equipment Co. Equipped with Globar elements and designed for continuous duty, the FG-76 performs efficiently at all temperature levels up to 2500° F., with even higher temperatures available

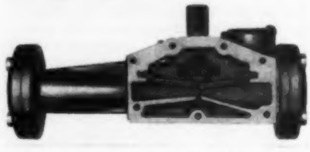
for short or intermittent runs. A voltage regulating type of transformer is used to maintain a constant rate of heating, to compensate for the change in element resistance through normal usage, and to give flexibility of operation. Power requirements are 15 kw. at 220 volts, 3 phase, 60 cycle. Chamber size is 8 by 16 by 6 in.
For further information circle #1385 on literature request card on p. 32B

TEMPERATURE OF MOLTEN STEEL: An electronic detecting device, developed by Minneapolis-Honeywell, has brought reductions in the cost of the temperature-taking operation as well as greater accuracy of the measurements. In one mill the cost for each temperature reading by the conventional immersion thermocouple was five dollars; utilization of the new device dropped the cost to 20 cents. The new instrument, when immersed in the molten steel, signals the operator at the precise moment the maximum, or true, reading is obtained. Previously operators had to guess at this and consequently tended to leave the thermocouple unit immersed in the steel too long. This

usually resulted in disintegration of the expensive platinum thermocouple and has been one of the big drawbacks for universal adoption of the immersion thermocouple technique for steel temperature measurement.

For further information circle #1386 on literature request card on p. 32B

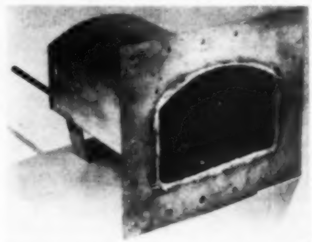
GAS-AIR MIXER: Changing heating loads on combustion equipment is simplified with a new Vari-Set mixer, by Eclipse Fuel Engineering Co. A built-in, adjustable orifice eliminates replaceable jets, and changes volume of automatically proportioned gas and air for any Btu. output within the



capacity of various sized mixers used in furnaces and other combustion equipment. Gas entrained by the air stream is automatically proportioned and a metering valve regulates the pressure for operating control equipment and for burning mixed, natural or L.P. gas.

For further information circle #1387 on literature request card on p. 32B

ANNEALING RETORT: A special alloy retort, by Allied Metal Specialties, Inc., for hydrogen bright annealing has dry hydrogen intake and dis-



charge lines arranged to give optimum gas utilization. Curved top structure provides additional capacity and tends to minimize distortion, thereby increasing service life.

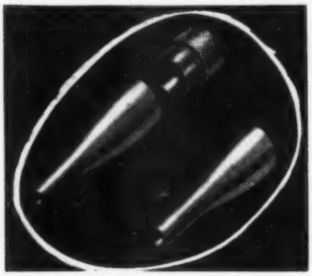
For further information circle #1388 on literature request card on p. 32B

DIE LUBRICANT: A new drawing compound X-60, developed by The Metalloid Corp., is said to increase production up to 8 times per die dressing by limiting heat that causes welding and pickup on the dies. Applicable for both simple and reverse dies, X-60 also gives improved surface finish. Applications in drawing operations include all conventional metals from

1010 low-carbon steel to stainless and numerous nonferrous materials. The lubricant can be applied by dipping the blank or shell, or may be atomized or sprayed on male and female dies. Dilutions are recommended according to the complexity of the draw. The product can be used in ratios up to 6 to 1, with any naphthenic or paraffin oil base. In addition to established applications for press operations, X-60 is being used in wire drawing service, and is undergoing cold rolling tests.
For further information circle #1389 on literature request card on p. 32B

ION EXCHANGE: The Enley reactor for ion exchange, including water demineralization, is designed to be used individually or in multiples for simple or complex ion-exchange processes. Because of the design flexibility of the reactor, it can be used as a pilot model prior to full-scale production. It also provides a low-cost water demineralizer which may be regenerated by the user.
For further information circle #1390 on literature request card on p. 32B

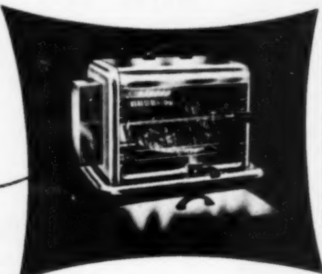
WELDING NOZZLES: Tru-Ohm Products Div. has announced their new ceramic welding nozzles for



Heliarc welding. Deep section welds are easily accomplished using these nozzles. The light metal adapter dissipates welding heat readily.
For further information circle #1391 on literature request card on p. 32B

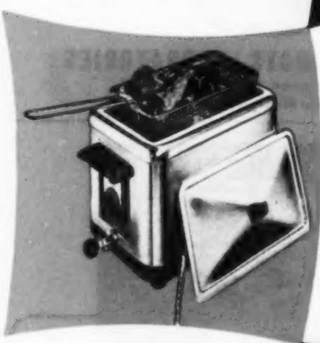
TEST GAGE: The 6-in. Model P test gage, made by The Foxboro Co., not only serves in checking pressure controllers, recorders and indicators, but also furnishes a standard of accuracy for calibrating other pressure testing equipment in the instrument department. The 6-in. gage is furnished in ranges of 0 to 30 Hg vac. up to 0 to 10,000 psig., and is guaranteed accurate within ½ of 1% of the total scale at any point throughout its range. The measuring element is a full 270° Bourdon spring of steel or beryllium copper.
For further information circle #1392 on literature request card on p. 32B

PRODUCT BEAUTY MORE THAN SKIN DEEP



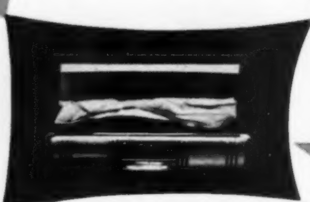
Takes the STING from production time

Puts ZING into your entire line!



LEARN MORE about Nickeloid Metals; see how they may be applied to YOUR product. We will be glad to have a sales engineer call on you, to submit prices and working samples. Sales offices are maintained in most of the leading cities. Write us, or consult your local telephone directory.

The beauty of the American Nickeloid metal-finished products goes *way* down deep. Past the lustrous finish of the Pre-Plated Metals . . . all the way back to the production line! Here Nickeloid Metal parts are simply (1) *Fabricated*, then (2) *Assembled*. No cleaning, plating or polishing needed because Nickeloid Metals are furnished in sheets, strips, or coils — all ready for window display! As you look at these eye-catchers, remember that the reduced manufacturing cost looked beautiful on the profit ledger, too!



NICKELOID METALS (Pre-Plated)

NICKEL · CHROMIUM · BRASS · COPPER
Electro-plated TO ALL COMMON Base METALS
ALSO LACQUERED COLORS
SHEETS AND COILS

OLDEST AND LARGEST PRODUCERS OF PRE-PLATED METALS

AMERICAN NICKELOID COMPANY

PERU 18, ILLINOIS

What's new IN MANUFACTURERS' LITERATURE

1401. Air-Gas Mixture
Engineering and application data on air-gas proportional mixer in Bulletin L-300. *Eclipse Fuel Eng'g*

1402. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1403. Alloy Steels
17-page booklet, "Alloy Steels and How to Get the Most Out of Them", contains seven case histories selected from widely varied fields. *Republic Steel*

1404. Aluminum Alloys
36-page book on analysis of aluminum, brass, bronze alloy specifications. *Sonken-Galamba Corp.*

1405. Aluminum Bronze
Bulletin PI-3 gives complete information on aluminum bronze for corrosion-resistant service. *Ampco Metal, Inc.*

1406. Aluminum Castings
135-page spiral-bound book describes the aluminum casting alloys, foundry principles and practice, design considerations and heat treatment. *Alcoa*

1407. Aluminum Castings
8-page description of the mold-making process of Morris Bean, used in production of aluminum castings of highest metallurgical quality. *Morris Bean & Co.*

1408. Aluminum Castings
Brochure "How To Cut Die-Casting Finishing Costs" deals with aluminum castings. *Monarch Aluminum*

1409. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

1410. Aluminum Melting
Folder A-5 describes automatic melting and pouring unit for production of aluminum die castings. *Ajax Eng'g*

1411. Aluminum Piston
6-page data book on the steel-belted aluminum piston. Construction and advantages. *Thompson Products*

1412. Aluminum Tubes
24-page bulletin on heat exchanger tubes of Alclad 3S and bare 3S. Specific application data, including allowable working pressures. *Alcoa*

1413. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

1414. Analytical Balance
Pamphlet on analytical balance having automatic indication of end result by projection of enlarged image of true micrometer scale. *Sartorius Div.*

1415. Atmosphere Furnace
Illustrated bulletin describes new controlled atmosphere furnace. *Industrial Heating Equipment Co.*

1416. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

1417. Barrel Finishing
22-page book gives facts and figures on barrel finishing, tells how single-unit installation may yield savings up to 95% on various parts. *Almco Div.*

1418. Barrel Finishing
20-page bulletin on burnishing materials, finishing barrels. Six steel burnishing shapes explained. *Abbott Ball*

1419. Barrel Plating
8-page booklet on fully automatic barrel-type plating and processing machines. Automatic methods of loading and unloading. *Frederic B. Stevens*

1420. Barrel Plating
Folder describes equipment for barrel plating with unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply*

1421. Belt Polishing
8-page booklet gives four case histories of backstand-belt polishing. *Armour*

1428. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1429. Brazing Alloy Washers
Free sample of silver brazing alloy preformed washer coined from wire. *Lucas-Milhaupt Engineering Co.*

1430. Bright Carburizing
Case history on bright carburizing of SAE 8620 bull gear pinions. *Ipsen*

1431. Bronze
12-page technical bulletin on seven grades of bearing bronze. Six case histories. *American Crucible Products*

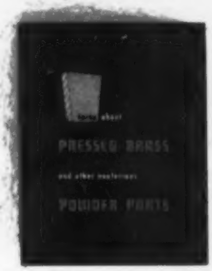
1432. Burners
16-page Bulletin 1220 on small-capacity long-flame burners, gas, oil, or gas and oil. *Bloom*

1433. Burners
Bulletin on combination gas and oil burner with high rate of combustion. *Ra-Diant Products Co.*

1580. Powder Metals

Is there a less costly method of making the part? The answer to your version of this question may be found in "Facts About Pressed Brass and Other Nonferrous Powder Parts"★, a guide for screening potential applications. Twenty-four case histories of commercial parts are presented in five groups: original powder metallurgy designs, conversions from sand castings, conversions from screw machinings, conversions from stampings, and five other conversions. For each of the 24 parts, tolerances, speed of production, cost and savings compared with other methods are covered in gratifying detail.

Part of the story is presented in broader terms than are possible in case histories. A 12-page section discusses size, shape, strength, accuracy, machining, finishing, speed and cost of the powder metallurgy method. Also included are definitions of 23 powder metallurgy terms used in the book and a list of 15 M.P.A. Standards.



The decision to use or not to use powders for a given part is seldom a simple one. This book will help the engineer or metallurgist to make his decision on a sound basis of producibility at least cost.

★Published by The New Jersey Zinc Co. Copies are available at no charge to readers of Metal Progress who circle No. 1580 on the literature request card, page 32B.

1422. Bending Aluminum
Bending formulas and radii for 90 and 180° cold bending of various grades and tempers of aluminum. From "Technical Advisor No. 18". *Reynolds Metals*

1423. Billet Shear
Folder on high-production billet shear with electromagnetic hold-down. *Maddaus-Moelders*

1424. Black Oxide Finish
Four-page article "Low-Cost Black Oxide Finish on Steel by Chemical Dip Method". *Mitchell-Bradford*

1425. Boron Nitride
Data Sheet 513B on properties and possible uses of boron nitride. *Norton Co.*

1426. Brazing Alloys
Booklet explains uses of phos-copper and phos-silver extruded alloys for torch, furnace and resistance brazing of copper, brass and bronze. *Westinghouse*

1427. Brazing Shim
Data Bulletin 707A on three-layer sandwich metal for brazing carbide tips to tools. *General Plate*

1434. Calcium Metal
16-page booklet on properties and potential uses of calcium metal in powder form. *Ethyl Corp.*

1435. Carbide
Brochure describes sintered chromium carbide for gage blocks. *Firth Sterling*

1436. Carbide Segregation
Effect of carbide segregation in tool steel. *Latrobe Steel*

1437. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical and process fields. *National Carbon*

1438. Carburizer-Nitrider
28-page Bulletin 646 on electric carburizing and nitriding furnace giving atmosphere circulation up to 1850° F. *Hevi Duty Electric*

1439. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

1440. Cast Irons
"Guide to the Selection of Engineering Cast Irons". *International Nickel*

1441. Chromium Cast Iron
48-page book on effects of chromium on properties of cast iron. Production and uses. *Electro Metallurgical*

1442. Chromium Plating
"How to Chromium Plate 20 to 80% Faster" describes self-regulating high-speed bath. *United Chromium*

1443. Clean Annealing
Article on atmosphere annealing of intricate stampings and cold drawn parts. *Sunbeam*

1444. Cleaner
Folder gives data on industrial metal cleaners for use with water in either still-tank or spray-washing equipment. *Solventol Chemical Products*

1445. Cleaner
Technical specifications for surface active agent used with both acid and alkaline cleaners. *Alrose Chemical Co.*

1446. Cleaners
40-page catalog of cleaning and finishing chemicals, solutions, and reagents. *Globe Chemical*

1447. Cleaning
Bulletin on equipment for cleaning and pickling of shell cases and other ordnance items. *Alvey-Ferguson*

1448. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

1449. Cleaning
Bulletin 6521 on vapor degreaser. Drawings, specifications. *Randall Mfg.*

1450. Cleaning
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

1451. Coated Abrasives
8-page booklet on how to store coated abrasives. *Armour*

1452. Coatings, Metal
High-vacuum evaporation of metals set forth in detail in 12-page booklet. *Distillation Products*

1453. Combustion Equipment
8-page folder on catalytic fume combustion. *Catalytic Combustion*

1454. Composite Metal
Data Bulletin 702B on copper-clad aluminum. Properties for six different combinations. *General Plate*

1455. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

1456. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

1457. Copper Tubing
6-page folder data on seamless copper tubing. Chart featuring safe working internal pressures for annealed and hard copper tubing. *Penn Brass & Copper*

1458. Corrosion Notebook
16-page "Corrosion Notebook" on corrosion resistance of various types of stainless tubing and pipe. *Carpenter Steel*

1459. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

1460. Cutting Compounds
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

1461. Definitions
36-page glossary of over 150 terms on cast iron. *International Nickel*

1462. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *Du Pont*

1463. Dial Gages
36-page catalog of dial gages of all types. *Nilsson Gage*

1464. Diamond Abrasive
4-page folder on the advantages of diamond abrasives for polishing metallurgical specimens. *Buehler Ltd.*

1465. Diamond Abrasives
8-page booklet on diamond abrasive, and catalog of diamond finishing accessory. *Elgin National Watch*

1466. Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1484. FORGINGS

Handsome 32-page brochure deals with two types of forgings — large and enormous. Specifically: generator and turbine shafts, rotors and spindles; drop hammer anvils and columns; rolls and sleeves; ship and general shafting. Many well-composed photographs show the big forgings in all attitudes of manufacture and repose. A short history of forging is included in the text. *United States Steel*

1467. Die Steel
Bulletin shows comparison of wear resistance, toughness and size rigidity for five grades of high-carbon, high-chromium die steels. Impact and hardness vs. tempering temperature. *Latrobe Steel*

1468. Dimensioning
40-page "Practical Dimensioning" tells how to avoid errors in the dimensioning of drawings. *Gisholt Machine*

1469. Dryer, Centrifugal
Bulletin gives specifications and drawings on centrifugal dryer for small parts. *Nobles Engineering and Mfg.*

1470. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1471. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1472. Electro-Clad Tubing
Bulletin on internally nickel plated steel tubing. *Bart Mfg.*

1473. Electroplating Aluminum
15-page Bulletin 7 on recommended practices for plating aluminum alloys with Cr, Ni, Cu, Ag, Au and brass. *Alcoa*

1474. Electro-Polarizer
Bulletin on instrument for precise polarographic analysis in chemical determinations on small samples. *Patwin Div.*

1475. Fasteners
22-page handbook of industrial fasteners. *Southco*

1476. Finish for Aluminum
Bulletin on Polychrome decorative metallic finishes for aluminum. *Alcoa*

1477. Finishing
20-page bulletin on mechanical finishing. Deburring, descaling, polishing, Britehoning, coloring. *Roto-Finish*

1478. Finishing Systems
Bulletin on cleaning and rust proofing equipment, spray booths and drying ovens. *Peters-Dalton*

1479. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Engrg.*

1480. Flow Meters
Catalog C-12 describes meters and accessories for measuring pressure, vacuum and differential pressure of liquids and gases. *Meriam Instrument*

1481. Flux, Aluminum Melting
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals & Metals*

1482. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

1483. Forgings
Catalog GI on upset and hammer forgings for various applications. *Commercial Shearing & Stamping*

1484. Forgings
See review on this page. *U. S. Steel*

1485. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Tables, drawings. *Merrill Bros.*

1486. Forgings, Automotive
Folder shows 31 forged parts for automotive industry. *Pittsburgh Forgings*

1487. Formed Parts
20-page brochure on fabricating components from metal wire, strip and other materials. Precision blanking, drawing, forming, wiredrawing and welding. *Parts Div., Sylvania Electric*

1488. Forming
32-page catalog on machinery for forming, cutting and punching operations on medium and light weight materials. *O'Neil-Irwin*

1489. Forming
32-page brochure describes universal contour former which combines stretch, compression, and radial-draw forming. Applications to extrusions, tubing, sheet, rolled and formed shapes. *Cyril Bath*

1490. Forming Dies
Data sheet gives information on roller dies for forming tubes, pipe and cold rolled shapes. For all roll forming machines. *American Roller Die*

1491. Foundry
36-page illustrated booklet dealing with foundry products, procedures and craftsmanship. *Lebanon Steel Foundry*

1492. Foundry Compound
Data sheets on moldable exothermic feeding compound for nonferrous and ferrous castings. *Foundry Services, Inc.*

1493. Foundry Practice
Article discusses gates and risers with special reference to nonferrous practice. *R. Lavin & Sons*

1494. Free-Machining Die Steel
Bulletin on properties, heat treatment and application of free-machining steel for die-casting dies and plastic molds. Hardenability and temperability curves. *Vanadium-Alloys Steel*

1495. Furnace Fixtures
16-page Catalog 16 on baskets, trays, fixtures, retorts and carburizing boxes for heat treating and quenching; 66 designs. *Stanwood Corp.*

1496. Furnaces
Bulletin 435 describes new furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

1497. Furnaces
Catalog on electric furnaces for tool room and general-purpose heat treating; also 600° F. ovens. *Cooley Electric*

1498. Furnaces
40-page book describes gas and electric furnaces and applications. Four basic types of atmospheres. Glossary of heat treating terms. *Westinghouse*

1499. Furnaces
6-page folder describes 18 typical installations of gas-fired and electric furnaces. Equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

1500. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in leaflet. *Carl-Mayer Corp.*

1501. Furnaces
16-page booklet "Proven Heat Treating Efficiency" displays complete line of furnaces. *Loftus Engineering*

1502. Furnaces, Atmosphere
Bulletin F-1 on versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200 to 2800° F. *Delaware Tool Steel*

1503. Furnaces, Laboratory
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

1504. Furnaces, Rotary Hearth
Folder giving drawings, dimensions, capacity, Btu required for drawing, annealing, forging. *Gas Machinery*

1505. Galvanic Coating
8-page booklet 452 on galvanic coating applied by brush. *Galvanite Corp.*

1506. Gas Analysis
Bulletins 804 and 805 on quick, accurate, direct analyses for oxygen and CO_2. *Bacharach Ind. Instrument*

1507. Gas Carburizing
Bulletin on gas carburizing in rotary furnaces. *American Gas Furnace*

1508. Gas Flow Meter
Bulletin 52-1017-37 on gas flow meter for furnace installations. *Hays Corp.*

1509. Gas Generator
Bulletin, "Make Your Own Gas", describes generator to convert oil to gas for standby or primary fuel. *Vapofier*

1510. Gear Hardening
Folder for application of induction heating to high-production hardening of gears. *Westinghouse*

1511. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

1512. Grinders
Catalog D-75 describes bench and floor-type wheel grinders, polishing lathes and backstands of various sizes and capacities. *Hammond Machinery*

1513. Grinding Titanium
Article on grinding wheels and techniques for titanium. *Norton Co.*

1514. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. *Lindberg Steel Treating Co.*

1515. Hardfacing
40-page Hard-Facing Manual tells what metals can be hardfaced, selecting right hardfacing material, step-by-step procedures and applications. *Haynes Stellite*

1516. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lbs. for portable and stationary use. *Andrew King*

1517. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 inches round and flat. *Ames Precision*

1518. Hardness Tester
Bulletin F-1689-1 on Impressor hardness tester for aluminum, copper, brass, bronze, plastics. *Barber-Colman*

1519. Heat Resistant Castings
New bulletin 952 on stainless and heat resistant castings. *Fahralloy*

1520. Heat Treating
Booklet describes facilities for heat treating steel, aluminum and magnesium. *Pearson Industrial Steel Treating*

1521. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam*

1522. Heat Treating Aluminum
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1523. Heat Treating Baskets
Data sheet on metal baskets for heat treating, quenching, nitriding, pickling and galvanizing. *Rose Iron Works*

1524. Heat Treating Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1525. Heat Treating Fixtures
Catalog B-8 describes and shows 75 custom-built fabricated alloy heat treating accessories. *Rolock*

1526. Heat Treating Fixtures
Extensive catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel Co.*

1527. Heat Treating Furnaces
Bulletin on gas, oil and electric furnaces of box and pot types for heat treating. *Dempsey Industrial Furnace*

1528. Heating Equipment
12-page bulletin on blowers and high-temperature fans. *General Blower Co.*

1529. High-Alloy Castings
48-page book describes almost 200 applications for heat and corrosion-resistant castings. *International Nickel*

1530. High-Alloy Castings
Bulletin FC-350 outlines advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry*

1531. High-Alloy Castings
New 28-page 3rd edition of "Nickel-Chrome Castings to Resist Heat & Corrosion". *Standard Alloy*

1532. High-Temperature Alloy
Bulletin describes "Incoloy", new nickel-chromium alloy for high temperature and corrosive environments. *International Nickel*

1533. High-Temperature Alloy
Data sheet on wrought alloy type 330, 35% Ni – 15% Cr. Mechanical properties of bars to 1800° F.; recommended design stresses to 2100° F. *Michigan Steel Casting Co.*

1534. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

1435. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 grades of high-temperature steel. *U. S. Steel*

1536. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

1537. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

1538. Induction Heat Control
Sheet 83 on miniature radiation detecting temperature-measuring device for flame hardening and induction heating. *Minneapolis-Honeywell*

1539. Induction Heating
12-page bulletin on equipment for induction heating. Requirements for hardening, brazing, and annealing at 1000, 3000, and 10,000 cycles. *General Electric*

1540. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics Co.*

1541. Induction Heating
Bulletin on low-frequency (60 cycle) induction heating furnace. Applications. *Magnethermic*

1542. Ion Exchange
24-page discussion of ion exchange resins and applications. *Rohm & Haas*

1543. Iron, High Chromium
"Abrasion-Resistant High-Chromium Iron" on how to make and use abrasion-resistant iron castings efficiently. *Electro Metallurgical*

1544. Laboratory Furnaces
Series of data sheets give full information on complete line of laboratory furnaces for numerous metallurgical operations. *Boder Scientific*

1545. Laboratory Safety
40-page booklet includes recently developed data, techniques and equipment, and provides useful manual for setting up complete laboratory safety programs. *Fisher Scientific*

1546. Leaded Steels
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

1547. Leak Detector
16-page bulletin on leak detector for location and measurement of leaks in evacuated or pressure systems. *Distillation Products*

1548. Liquid Carburizing
New technical bulletin describes use and operation of water-soluble liquid carburizing baths. *Park Chemical*

1549. Lockseam Tubing
Blueprint of size ranges of round or oval lockseam tubing in a wide range of metals. *H & H Tube and Mfg.*

1550. Low-Temperature Tests
Bulletin MC-1 on cryostat that maintains a test chamber from room temperature to within 2° of absolute zero. *Arthur D. Little*

1551. Low-Temperature Tests
62-page bulletin on equipment for low-temperature tests. *Bowser Technical Refrigeration*

1552. Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1553. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

1554. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

1555. Magnesium Finishing
128-page book describes all methods for finishing magnesium. *Dow Chemical*

1556. Magnetic Alloys
8-page booklet 52-100 gives properties and uses of Hipernik, Conpernik, Hiperco. *Westinghouse*

1557. Magnetic Alloys
20-page bulletin on the more important "magnetically soft" iron-nickel alloys. *International Nickel*

1558. Mechanical Cleaning
76-page catalog 210 simplifies selection of power brushes; various types of brushes in operation. *Osborn Mfg.*

1559. Melting Furnaces
8-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to all types of casting. *Lindberg Engineering*

1560. Metal Cutting
64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

1561. Metal-Cutting Saws
Circular saw blades described, with data on standard sizes and sharpeners. *Motch & Merryweather*

1562. Metal Saws
Folder on new band saw of 24 by 24 in. capacity. *W. F. Wells & Sons*

1563. Metal Spraying
Folder on processes and uses; metallizing for mechanical repairs and corrosion protection. *Metalweld*

1564. Metallographic Polishing
Booklet describes line of two-speed polishers. *Buehler Ltd.*

1565. Metals Comparator
Bulletin GEC-566 on electronic quality control equipment which indicates hardness variations by magnetic measurements. *General Electric*

1566. Modulus Determination
Data sheet on equipment for determination of modulus of elasticity by sonic method that measures resonance frequency of masses weighing up to 1500 lb. *Electro Products Laboratories*

1567. Ni-Carb Treatment
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

1568. Nickel Plating
12-page reprint, "Mechanical Properties of Nickel Deposits", deals with effects of plating variables on properties. 13 charts, 3 tables, 40 micrographs. *International Nickel*

1569. Nondestructive Testing
Data on electronic inspection equipment and comparators for sorting. *Magnetic Analysis*

1570. Nonferrous Tubing
Bulletin on seamless, brazed and lock-seam tubing in brass and copper. *H & H Tube and Mfg.*

1571. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1572. Oil Burner
Bulletin C-220 on design and operation of new low-pressure-air atomizing oil burner. *Bloom Engineering*

1573. Pearlitic Malleable
Folder 12 on properties of pearlitic malleable iron. *Belle City Malleable Iron*

1574. Peening
Bulletin on use of cut wire shot for peening and cleaning. *Park Chemical*

1575. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes", gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

1576. Photography
12-page Bulletin MPU on universal camera for low-power photography on film or plates. *Gamma Instrument Co.*

1577. Pickling Solutions
Bulletin 36 on D-scale RS, substitute for liquid pickling. *Magnus*

1578. Plating Racks
8-page booklet offers data on a plating rack designed to make the spline section or body of the plating rack a permanent tool. *National Rack*

1579. Polishing
Catalog A-60 on polishing lathes up to 3600 rpm. *Hammond Machinery*

1580. Powder Metallurgy
See review on page 25. *New Jersey Zinc Co.*

1581. Powder Metallurgy
Information on sponge iron powder. *Ekstrand & Tholand*

1582. Precision Casting
8-page bulletin on investment castings of ferrous and nonferrous alloys. *Engineered Precision Casting*

1583. Precision Casting
12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields. *Alexander Saunders & Co.*

1584. Precision Castings
12-page booklet, "Pour Yourself an Assembly", describes wide range of applications and alloys for precision casting. *Precision Metalsmiths*

1585. Precision Castings
Illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Labs.*

1586. Precision Castings
Bulletin 706 on the Mercast frozen mercury process of investment casting. *Alloy Precision Castings*

1587. Precision Strip
Thin-gage and clad metals, as well as precious metal strips, wire and powder, which are still available, are listed in Bulletin 9-B. *American Silver*

(Continued on p. 32-A)

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(Continued from p. 31)

1588. Pre-Plated Metals
16-page fabrication handbook on pre-plated metals, ferrous and nonferrous. *American Nickeloid*

1589. Protective Coating
Reprint on zinc-containing protective coating applied like paint. *Industrial Metal Protectives*

1590. Pump for Liquid Metal
Bulletin 876 on electromagnetic pump for pumping liquid metal having electrical resistance equal to or less than stainless steel. *General Electric*

1591. Punching and Shearing
Bulletin on machine that combines in one unit a punch, bar and shape cutter, coper and shear. *Maddaus Moelders*

1592. Purification of Plating Solutions
Bulletin 26 on purification of nickel plating solutions with hydrogen peroxide. *Buffalo Electro-Chemical*

1593. Pyrometers
Information on Xactemp pyrometers; also Xactline straight-line temperature control for use with any standard controller. *Claud S. Gordon Co.*

1594. Quench Tank Conveyor
8-page bulletin on continuous quench tank conveyor. *Klaas Machine & Mfg.*

1595. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton & Co.*

1596. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil Co.*

1597. Radiography
34-page book on X-ray applications features radiography of castings and weldments. *X-Ray Dept., Gen. Electric*

1598. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse*

1599. Recirculating Furnaces
16-page Bulletin 81 describes and illustrates heat treating furnaces for ferrous and nonferrous parts and other heat treat equipment. *Despatch Oven*

1600. Recorder Controllers
48-page catalog ND 46(1) gives specifications, numerous installation pictures of recorders and controllers for temperature, stress, strain and other variables. *Leeds & Northrup*

1601. Recording Potentiometer
14-page folder on simplified single-point recorder of the potentiometer type. *Weston Electrical Instrument*

1602. Refractories
Bulletin 316 on Sillimanite refractories for the iron and steel industries. *Chas. Taylor Sons*

1603. Refractories
52-page book on background, materials used, and design of various types of refractory enclosures for furnaces, soaking pits, catalyst regenerators. *M. H. Detrick Co.*

1604. Refractory
12-page brochure on new magnesite-chrome refractory, electrically melted and cast, for steel melting. *Corhart Refractories*

1605. Reverse-Current Cleaner
Bulletin on electrocleaner 12 for steel, copper and brass with either reverse or direct current. *Diversey*

1606. Rhodium Plating
Directions for rhodium plating, with reference to use as replacement for usual plating metals. *Baker & Co.*

1607. Rocket Nozzles
Data Sheet 522 on four materials of promise for rocket nozzles. *Norton Co.*

1608. Rolling Mills
Folder on 3x5 in. flat and wire mills. *Stanat Mfg.*

1609. Rotary Straightener
Catalog describes two-roll rotary straightener for round tubes and bars $\frac{1}{16}$ to $\frac{3}{8}$ in. o.d. *Medart Co.*

1610. Salt Bath Descaling
12-page bulletin B-40 describes continuous and batch descaling lines for removing oxide from steel, bronze, copper, stainless and titanium. *Drever Co.*

1611. Salt Bath Furnaces
Illustrated folders give data on salt bath furnaces for batch and conveyorized work. *Upton Electric Furnace*

1612. Salt Baths
28-page booklet deals with heat treatment, carburizing, bath maintenance, safety precautions. *American Cyanamid*

1613. Salt Baths
75-page manual on salt baths for case hardening and heat treating. *DuPont*

1614. Salt Spray Testing
Bulletin on lucite salt spray testing cabinet. *Singleton Co.*

1615. Selective Heat Treating
Reprint 73 describes new method of selective heat treating in a salt bath. *Ajax Electric*

1616. Set Screws
20-page catalog and reference book on set screws. *Set Screw & Mfg.*

1617. Shears, Metal Cutting
16-page catalog on pivoted-blade shears for cutting metal up to 1.25 in. thick. *Cleveland Crane & Engineering*

1618. Sheet Metal Testing
8-page folder on equipment fo[r] ing drawing, stamping, compressi[n] folding qualities of sheet and str *Arthur Deakin*

1619. Shell Molding
Data sheet on new synthetic re[s] bonding shell molds. *Borden Co.*

1620. Shell Molding
8-page technical bulletin on molding process for stainless *Cooper Alloy Foundry*

1621. Shot Peening
Catalog describes selection and shot and grit for cleaning and pe *Cleveland Metal Abrasive*

1622. Soldering Equipmen
8-page brochure on solderin[g] brazing equipment describes new soldering gun and shows its ap tions to production-line solderin brazing. *Metallizing Co. of Ameri*

1623. Solvent Cleaning
24-page brochure on mediu cleaner for following solvent degr or other precleaner. *Northwest Ch*

1624. Sonic Thickness Tes
Bulletin on measurement of wall thickness from one side by method. *Branson Instruments*

1625. Spark Testing
20-page spark test guide fe spark diagrams of 13 standard to die steels. *Carpenter Steel*

1626. Specification Key
Guide to Government specific for phosphatizing, rust proofin paint bonding chemicals. *Am Chemical Paint*

1627. Stabilized Stainless
26-page reprint, "Conservation lumbium", a summary of Britis American experience with sta stainless steels. 56 contributors relative acceptability of titaniu columbium for stabilized stainles Aircraft, chemical, petroleum a tions; welding, forming; tubing ings, sheet, plate, bars, electrodes. *Progress*

1628. Stainless, Type 430
12-page book on fabrication a of Type 430 stainless steel. *Sharo*

1629. Steels, Spring
Spring steel catalog offers 652 hardened and tempered spring and 133 cold-rolled and bright an sizes in stock. *Sandvik Steel*

1630. Straightening Tube
8-page Bulletin 52 on experie seven plants with rotary straigh for tubular products. *Mack Hemphill*

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1631. Subzero Freezer
8-page folder on portable freezer, 110-volt, a.c., operating to —180° F., for shrink fitting, hardening, stabilizing and testing. *Webber Appliance*

1632. Subzero Thermometer
Information on recording thermometer for temperatures as low as −200° F. *Dickson*

1633. Surface Grinding
54-page guidebook on use of disk grinders for grinding flat surfaces. *Gardner Machine*

1634. Surface Hardening
Booklet on nonpoisonous, nonexplosive and nonflammable surface hardening compounds. Illustrations and engineering charts. *Kasenit Co.*

1635. Surface Temperatures
Pyrocon bulletin on hand-held thermocouple-type instrument for measuring and indicating surface temperatures at exact locations. *Illinois Testing Labs.*

1636. Tank Liners
Corrosion data on Koroseal tank linings in contact with plating baths and other corrosive solutions. *Metalweld*

1637. Tank Liners
Technical data on hard vinyl material for corrosion resistant tanks and tank linings for electroplating. *American Lucoflex*

1638. Tank Linings
12-page Bulletin 526 on thermoplastic lining material. Tabular data on chemical resistance. *U. S. Stoneware*

1639. Temperature Control
New catalog G-17 on temperature control instruments. *Burling Inst.*

1640. Temperature Control
Catalog of pyrometer supplies gives data on thermocouples, protection tubes, other accessories. *Arklay S. Richards Co.*

1641. Temperature Control
8-page section on signalling temperature controllers of the resistance bulb type. *Thermo Electric*

1642. Testing
Booklet on Reflectoscope tells how ultrasonic vibrations penetrate up to 24 feet to "see" internal defects and fatigue cracks. *Sperry Products*

1643. Testing Machines
28-page catalog on screw power universal testing machines and accessories. Details of construction and specifications. *Riehle*

1644. Thermocouple Accessory
Bulletin TC-1 on accessory for sealing unshielded thermocouple wires in any chamber operating at pressures from 15,000 psi. down to full vacuum. *Conax*

1645. Thermocouple Data
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

1646. Thermocouples
36-page Bulletin 235-4 describes various types of thermocouples, extension wire and other accessories. *Foxboro*

1647. Tin
24-page book on production, consumption and uses of tin. *Malayan Tin Bureau*

1648. Titanium
30-page data book on properties of commercially pure and alloy titanium, melting, forging and rolling. 16 charts and micros; 4 hardness conversion curves for titanium. *Republic Steel*

1649. Titanium
16-page bulletin, "The Hydrimet Process", describes titanium and zirconium metal and hydride, and other metallurgical hydrides. *Metal Hydrides*

1650. Tool Furnace
17-page Bulletin 1054 on tool hardening equipment. *Sentry*

1651. Tool Steel
20-page booklet on selection of proper tool steel support material for use with carbide tools. *Allegheny Ludlum*

1652. Tool Steels
Stock list of available tool and die steels. *Reliable Steel*

1653. Transition Manufacturing
16-page brochure on service which bridges gap between development engineering and commercial production. *Cambridge Corp.*

1654. Tubes and Bars, Steel
New stock list on 52100 tubing, bars, and ring forgings. *Peterson Steels*

1655. Tubing
Bulletin 32 on analyses available, production limits, commercial tolerances, temper designations of seamless and weldrawn tubing. *Superior Tube*

1656. Tumbling Barrels
10-page Catalog B-8 gives specifications, applications of six types of tumbling barrels. *Globe Stamping Div.*

1657. Tungsten Electrodes
Wall chart gives data for inert-gas arc-welding of aluminum, magnesium, stainless steel with pure and thoriated tungsten electrodes. *Sylvania*

1658. Vacuum Metallizing
Folder on tungsten filaments for use in vacuum metallizing. Both flat sheet and formed wire heaters. *Sylvania*

1659. Vanadium Recovery
6-page article, "Recovery of Vanadium and Other Alloys in the Acid Electric Furnace". *Vanadium Corp.*

1660. Vapor Degreaser
Vapor degreaser described and diagrammed in folder. Data on different models. *Topper Equipment*

1661. Volt-Ammeter
Folder on clamp-type, hand size instrument for use on a.c. to 600 amp., 600 v. *Columbia Electric Mfg.*

1662. Water Purity
Folder on device for testing purity of water and controlling flow. *Barnstead*

1663. Water Softener
16-page Bulletin 2386 explains three basic types of ion-exchange equipment. *Permutit Co.*

1664. Welding Electrodes
Application chart for stainless, alloy and nonferrous electrodes. *Weldwire*

1665. Welding Equipment
Cadweld process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

1666. Welding Stainless Steels
"The Welding of Stainless Steels" devotes 48 pages to arc welding. Metallurgy and alloying elements. *McKay Co.*

1667. Welding With Bronze
Reprint describes techniques and choice of bronze electrodes for welding various copper, steel and cast iron subassemblies. *Ampco Metal*

1668. Weldments and Castings
24-page book, "Facts About Weldments and Castings", gives basic engineering facts about plate fabrication vs. castings. *Acme Tank & Welding*

1669. Wire Fabrication
16-page handbook on applications and fabrication of wire. 12 case histories. *E. H. Titchener & Co.*

1670. X-Ray Inspection
Bulletin entitled "Industrial X-Ray for Nondestructive Inspection and Testing". *Keleket X-Ray*

1671. X-Ray, Portable
Specifications for lightweight, portable 260 kvp. industrial X-ray machine. *Triplett & Barton*

1672. X-Ray Spectrography
Publication AO-11, "Metallurgical Applications of X-Ray Fluorescent Analysis". *X-Ray Dept., Gen. Electric*

1673. Zinc Die Castings
Folder on small parts applicable to die casting. *Dollin*

1674. Zirconium
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Titanium Alloy Mfg.*

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1394	1420	1446	1472	1498	1524	1550	1576	1602	1628	1654	
1395	1421	1447	1473	1499	1525	1551	1577	1603	1629	1655	
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But using the *right* salt is essential for precision heat treating. Many a metalworking plant like yours is getting accurate control of temperature . . . within 5° F. either way . . . by specifying the Houghton salt bath developed for the job.

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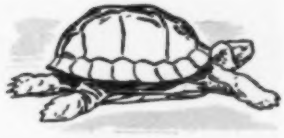

Case Hardening Problems Are Rare among users of Houghton "Perliton" . . . the liquid salt bath carburizer with a "blanket" of carbon over the bath surface which prevents surface oxidation. If you want faster carburization and more uniform parts, try "Perliton."

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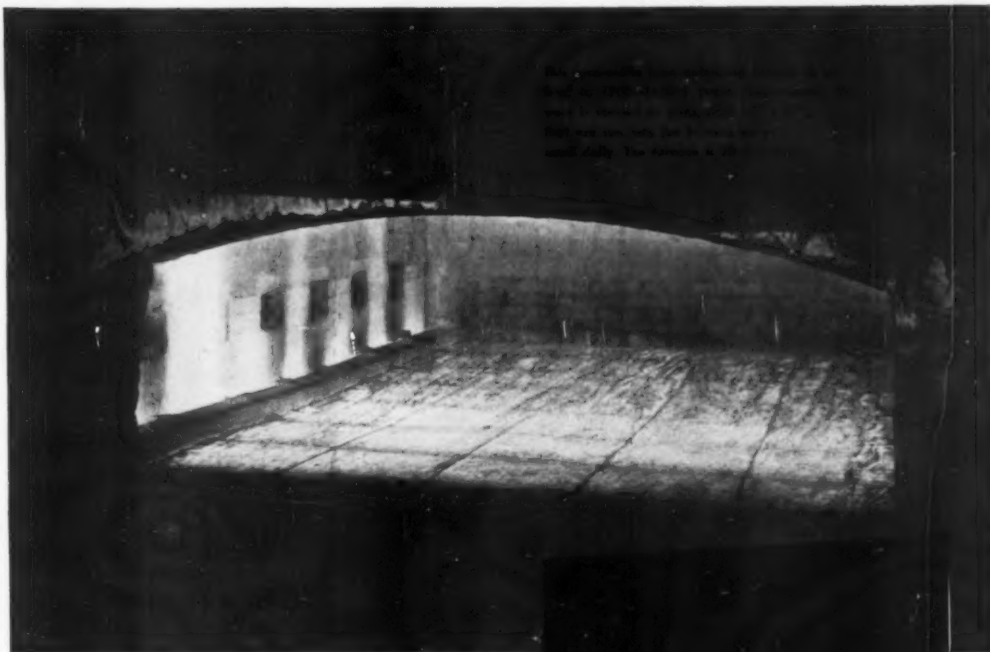

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contains latest information on

TABLE OF CONTENTS

√ **Methods**

√ **Materials**

√ **Preparation**

√ **Procedure**

The expanding use of magnesium, its extensive possibilities and the ever-increasing interest in this ultralight metal have resulted in a demand for more information regarding finishing procedures for magnesium products. Hence this book, which is a complete compilation of the latest information on magnesium finishes including: chemical treatments, painting methods and assembly protective measures.

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Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

These bolt-header parts represent some of the many uses at our Lebanon, Pa., plant for our carbon tool steel of cold-heading quality. As a large user of our own tool steels, we gain valuable experience to help solve our customers' problems.

How Our Proving Ground Helps Tool Steel Users

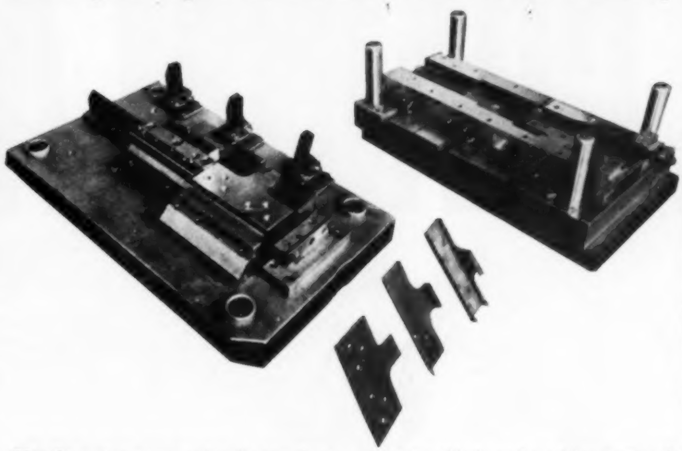
Many people think of a particular tool steel in terms of its chemical analysis. Others may classify it according to its properties. But when all's said and done, from the standpoint of the user a particular tool steel is one that does or doesn't do the job on a specific application.

We ourselves are one of our own largest tool steel customers. We use tons of Bethlehem tool steel every year. Our steel and manufacturing plants, our fabricating works and shipyards, make a vast proving ground, giving us very special opportunities to check up on our tool steel, watching it at work on nearly every kind of job imaginable.

That helps us — and our customers — in two ways. First, it yields the kind of first-hand practical experience in the treatment and application of the various grades of Bethlehem tool steel that can only be gained by living with them every day. Second, it provides a huge store of valuable information on tool design, heat-treatment, and tool and die performance.

All this helps not us alone but, as we say, helps us to help our customers to get the most out of tool steel. So if you have a problem in any way related to tool steel selection or treatment, we invite you to tell us about it. The chances are several to one that our experience can be helpful. It is yours for the asking.

Heavy-duty Die Packs 300-ton Wallop



This three-stage progressive die punches, shears, trims, and forms parts from steel plate in a 300-ton press. It turns out about 2500 each shift. All wearing portions of the die are made of 67 Chisel, our chrome-tungsten grade of shock-resisting steel. Hardened to Rockwell C-53, it produces upwards of 30,000 pieces before redressing is needed. The guard-rail clip angles, shown in foreground, are made from high-carbon steel plate of approximately .218 in. gage.

Renowned for its extreme toughness, 67 Chisel has excellent wear-resistance for a wide range of heavy-duty jobs. It's often used for punches, swaging dies, chipping chisels and machine parts subject to repeated shock . . . heavy shear blades for cold work and also for hot-work jobs up to 1000 F. And it's a popular choice for master hobs.

Tools made from 67 Chisel are readily carburized. This makes possible a very hard surface, reinforced by a core that's really tough.

67 Chisel is an easy steel to machine and heat-treat. It's stocked in many sizes for quick shipment.

Its typical analysis:

C	*Si*	*Cr*	*W*	*V*
.50	.75	1.15	2.50	.20

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Keep those cutting tools sharp

In many shops the resharpening of production cutting tools is neglected too long. In an effort to keep output at a peak, such tools are sometimes kept in use beyond the point where the cutting edges become excessively dull.

Just what happens when edges are dull? For one thing, the dull edges begin to cause an increase in the load on the shearing or cutting edges. If the dullness is carried to extremes, tools will break. Dull cutting edges also produce rough surfaces on the parts; this may result in rejection due to defects or because the tolerances have been exceeded.

If resharpening is delayed too long, it may be impossible to recondition a tool properly. Deep spalls, cracks, and gouges cannot be removed. Usually there is an economic balance point on each type of operation where it is best to resharpen. This point must be determined for each operation. Regular inspection of tools will show any unusual conditions causing excessive dulling.

Preventive maintenance of cutting edges pays off in longer tool life and fewer broken tools.

A few words about

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and how they are

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to produce greater uniformity

in your boron treated steels

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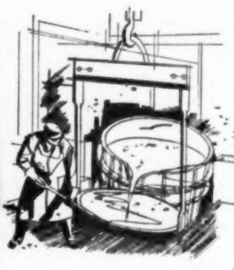
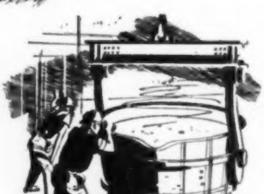


In our Plant exacting methods of production protect the quality of Grainal Alloys.



In your Mill, greater uniformity in your boron steels.

Uniformity. Consistent Results.

These are the demands of today's steelmaker. To make certain they are answered, we have *metallurgically engineered* our Grainal alloys.

In our laboratories, in our plant, every care is taken to insure a product of the correct composition and highest quality.

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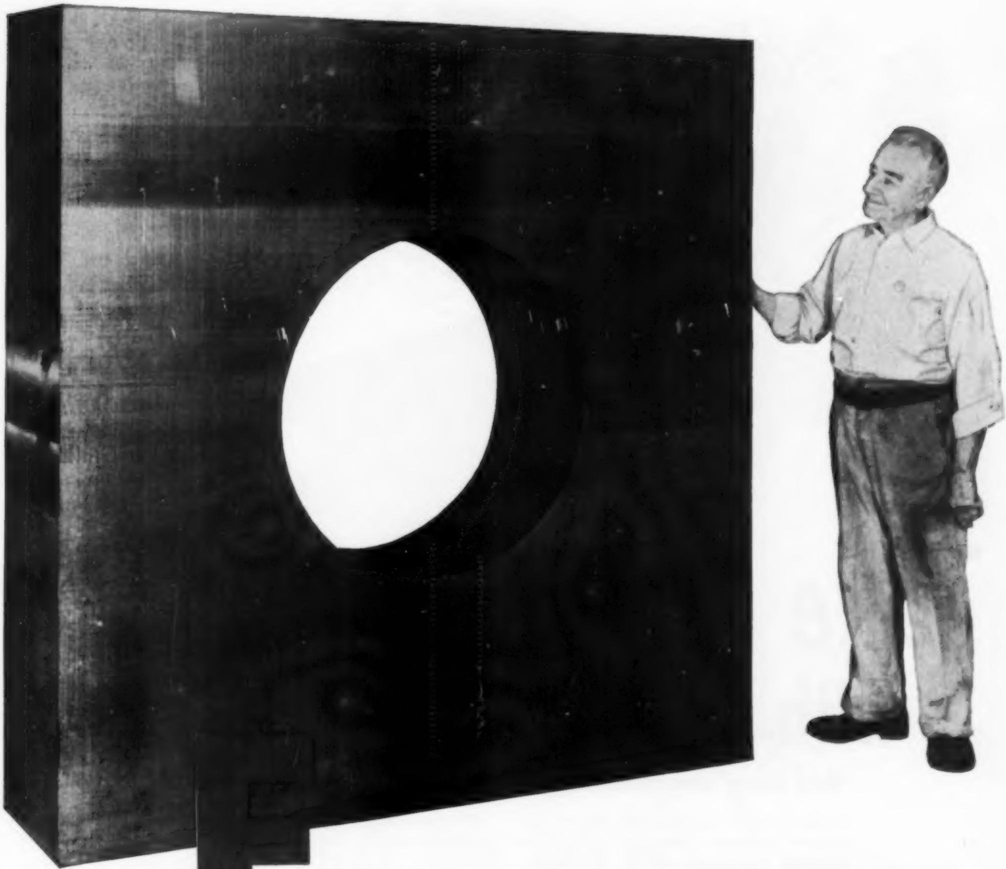

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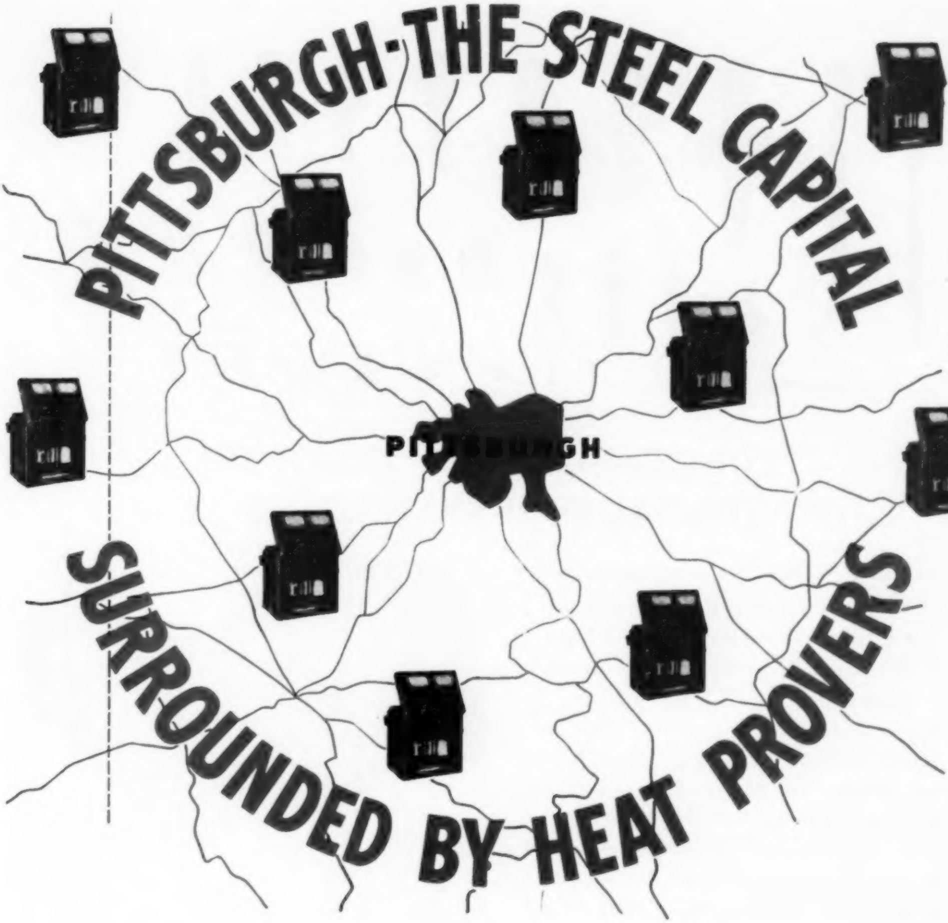

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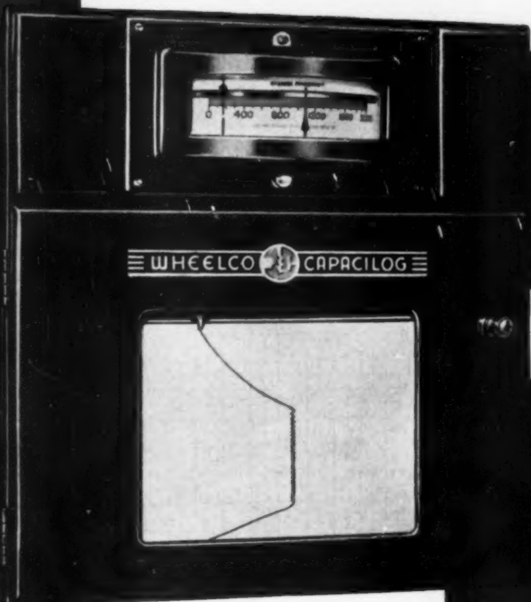

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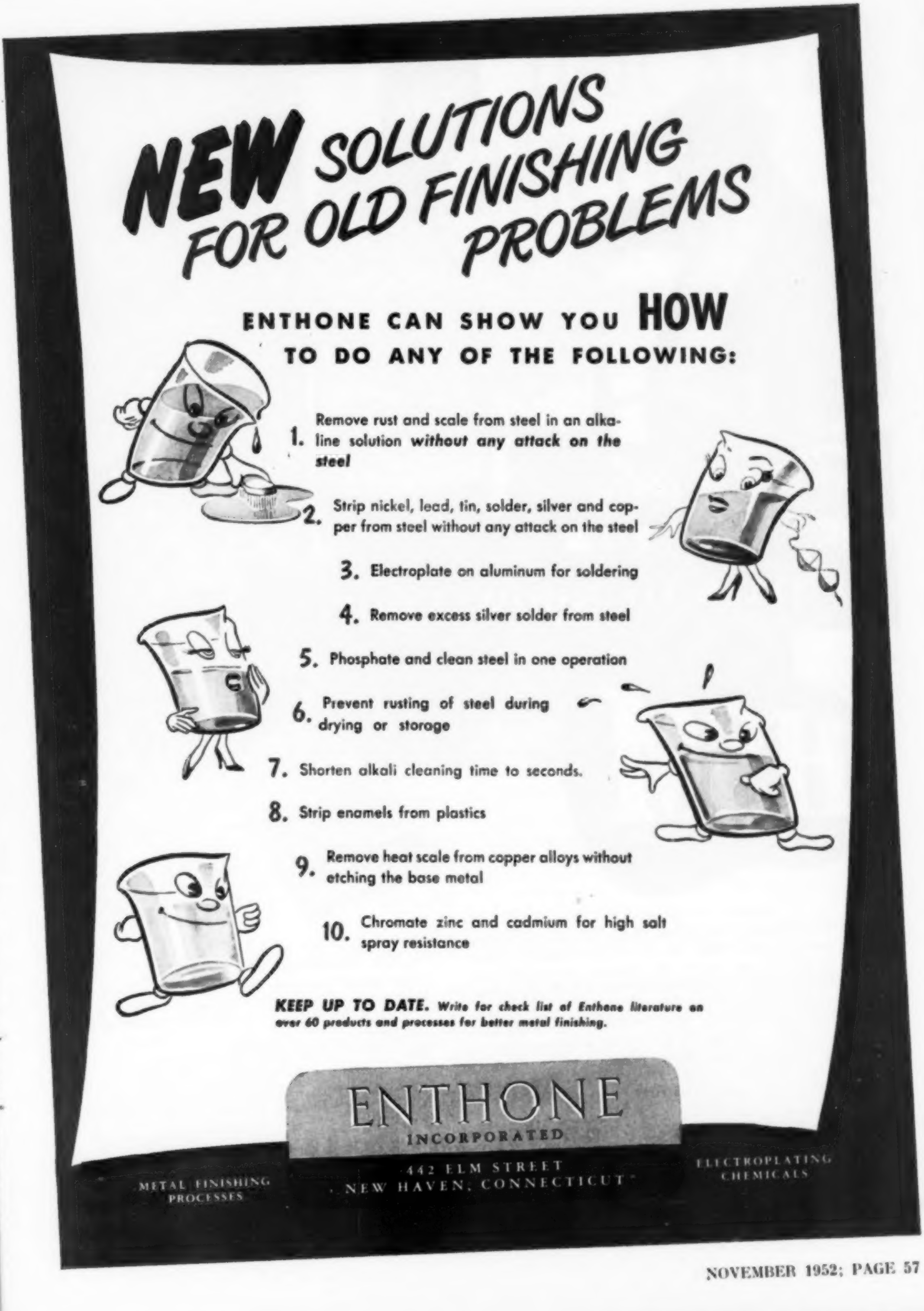
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Most stable tool steel ever made Outwears others 3 to 1 Machines 30% faster Minimum tendency to pick up, scuff or gall Uniform response to heat treatment	PLUS	No drilling Finish boring is first step Less machining time Less scrap loss More parts per ton of steel	EQUALS	"GRAPH-MO HOLLOW-BAR"

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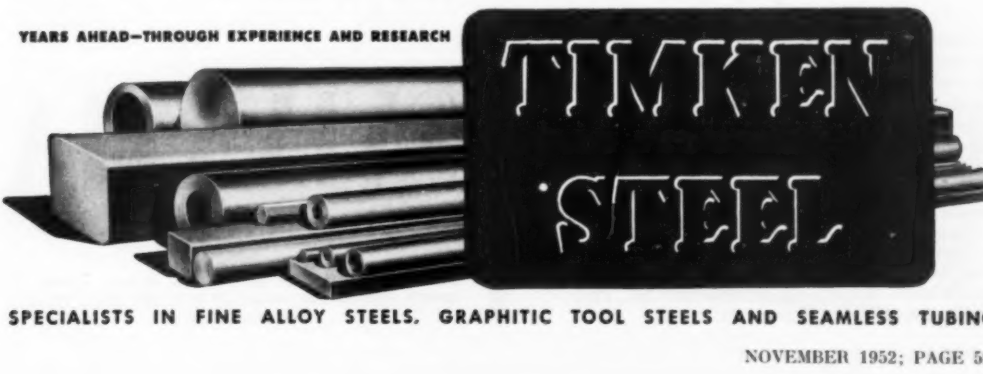

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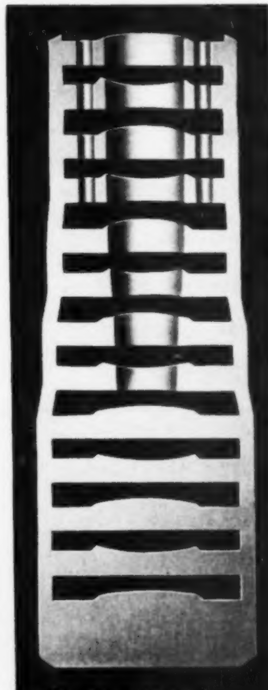

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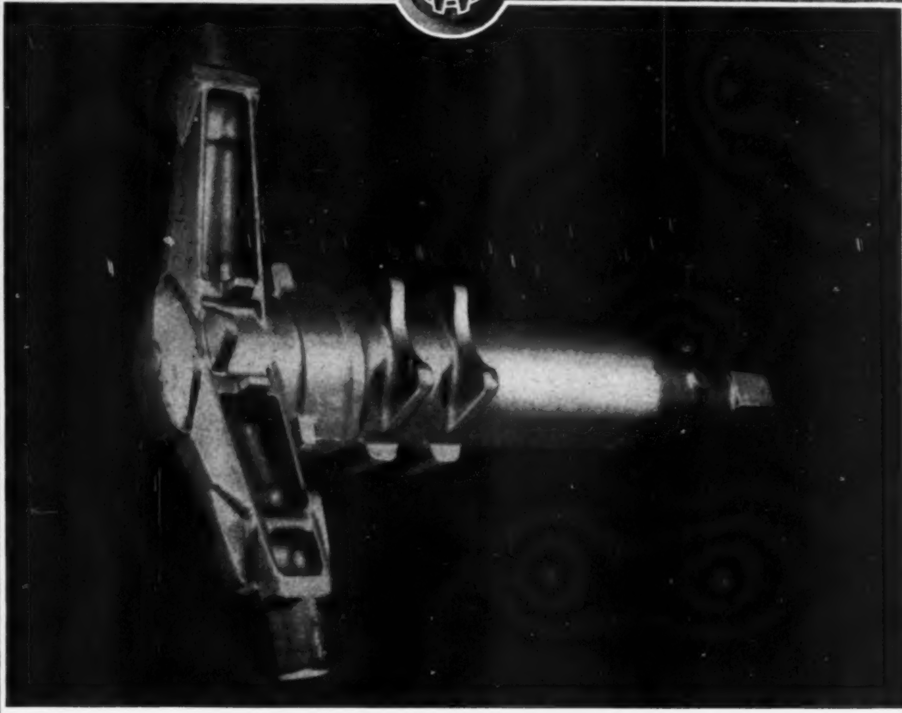

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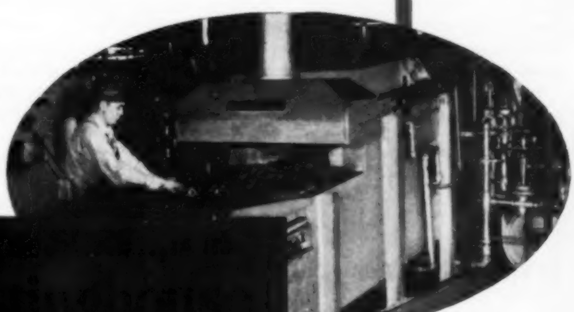

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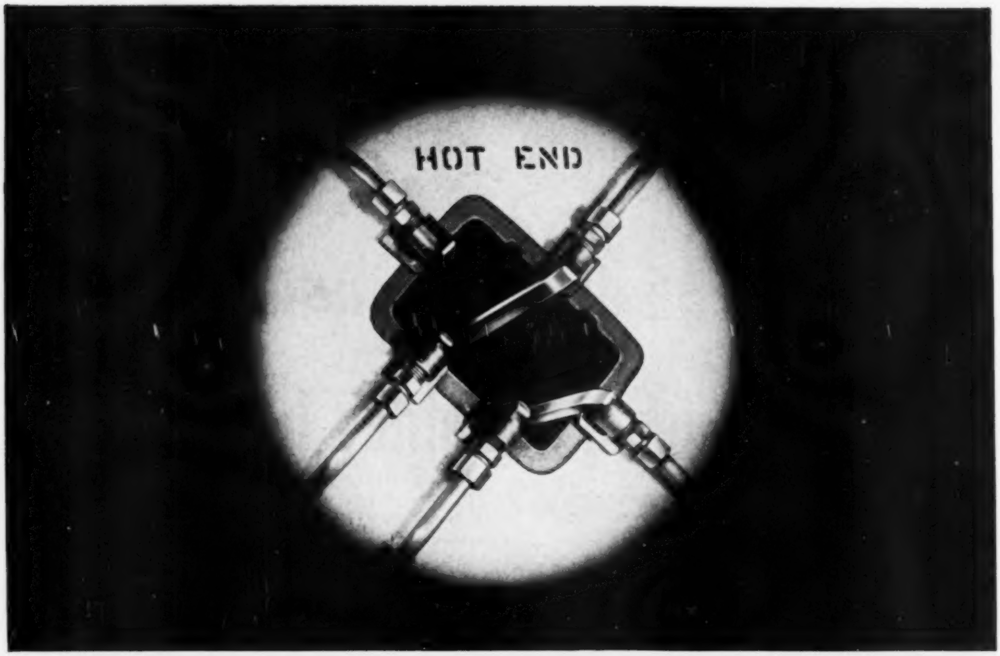
HEAT-TREATING FURNACES



The Superior Tube That Keeps Its Temper In A Hot Spot

Producing tubing and tubular parts that stand up well even when the heat's on is a Superior specialty.

One of these parts is shown above. It is a guide rail for a TOCCO† induction hardening furnace, manufactured by The Ohio Crankshaft Co., a Superior customer.

This simple tube has to be tough. Constantly exposed to high heat, it must retain its temper, stay hard. Continually abraded by the scrubbing action of the 25 pound hot-rolled steel slugs that ride along it, it must require infrequent replacement. In addition it must not crack when brazed, or develop cracks in use.

Reading this list of requirements would suggest that the guide rail must necessarily be a brute-strong, thick-walled, heavy-weight. It isn't—it is a ⅝″ square Inconel* tube with a wall only .065″ thick. It is another example of fine, small tubing that does a big job well.

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All analyses .010″ to ⅝″ O.D.
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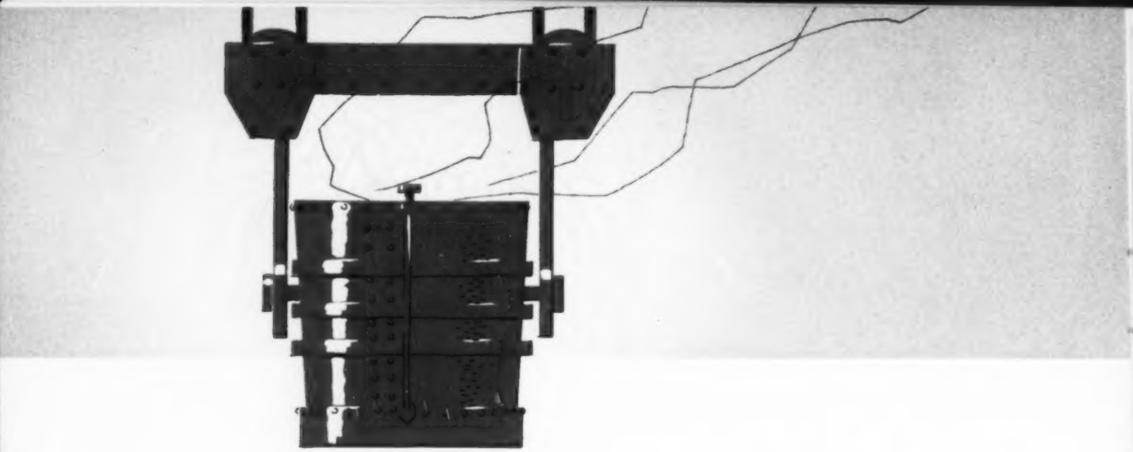

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So, it pays you to keep your interruptions few and far between. You can do it *only* with a refractory cement that fits your requirements exactly.

That's where Norton Refractory Research makes things easy for you. Tackling all kinds of high-temperature problems — complicated by chemical, electrical and physical variables — and coming up with special refractories to solve them has kept Norton Research busy for over 40 years. And you, too, can benefit from the findings of this research.

Whatever your problem, you can be sure that Norton Refractory Research has already licked it for somebody else . . . or is already working on it.

That's because Norton Research works with so many different refractories and compositions: CRYSTOLON* silicon carbide, ALUNDUM* fused alumina, MAGNORITE* fused magnesia, and the sensational new refractory FUSED STABILIZED ZIRCONIA.

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Chances are you, too, can melt more steel per lining by using Norton MAGNORITE cements. This applies to a wide variety of melts ranging from straight steel to heat-resistant compositions.

These cements have been developed specifically to be dry rammed and will withstand temperatures up to 3250 F.

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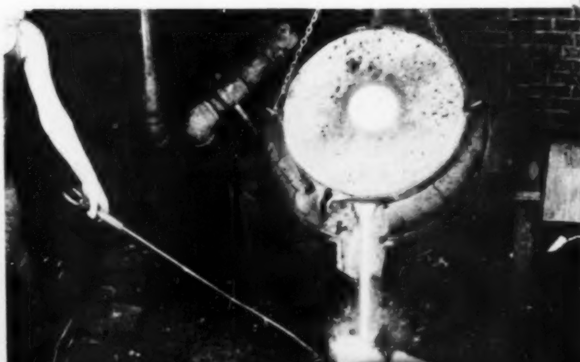
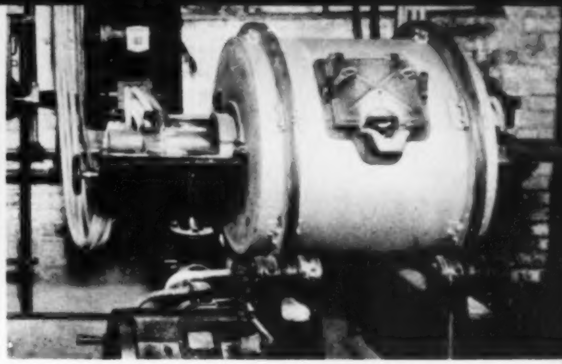
THIS LOW FREQUENCY INDUCTION FURNACE has a special Norton MAGNORITE refractory cement lining which gives such a high rammed density that it resists metal penetration and erosion longer.

THIS TILTING CRUCIBLE FURNACE has a pre-fired CRYSTOLON cover and lining of a Norton CRYSTOLON refractory cement which were engineered to fit this firm's individual requirements



THIS HIGH FREQUENCY INDUCTION FURNACE is lined with a Norton MAGNORITE cement designed specifically to be dry rammed and to withstand temperatures up to 3250 F.



THIS INDIRECT ARC FURNACE owes much of its high output to its lining, made of a custom-engineered Norton refractories cement.

ALUNDUM CEMENTS STAND UP

In desulphurizing ladles, which involve addition of sodium carbonate, Norton ALUNDUM cements have proved successful. One report from a gray iron foundry, using a 1500 pound "U" type ladle, shows an ALUNDUM cement lasting two to four times longer than any other refractory month in and month out.

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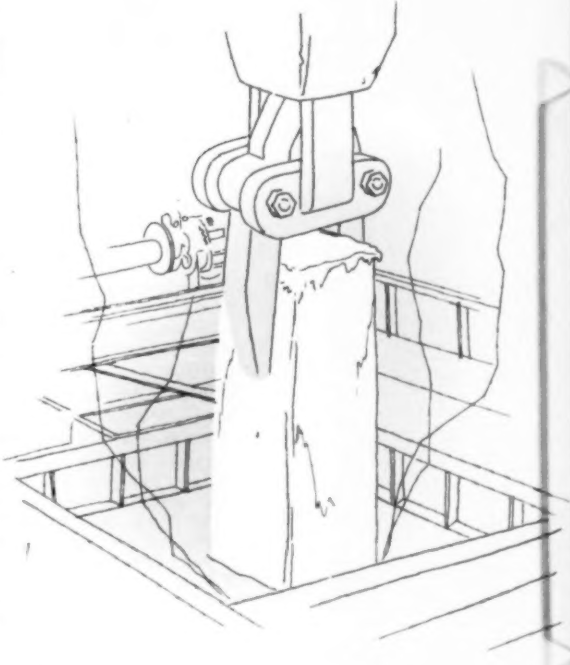
NOTE: In regards to thermal conductivity, make a note of this. Tests by independent laboratories using standard ASTM test methods prove that Norton CRYSTOLON silicon carbide brick, hearth plates, etc. equal or exceed in thermal conductivity any other silicon carbide shapes in use today.

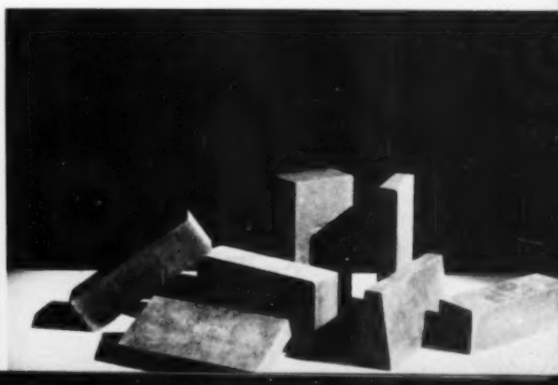


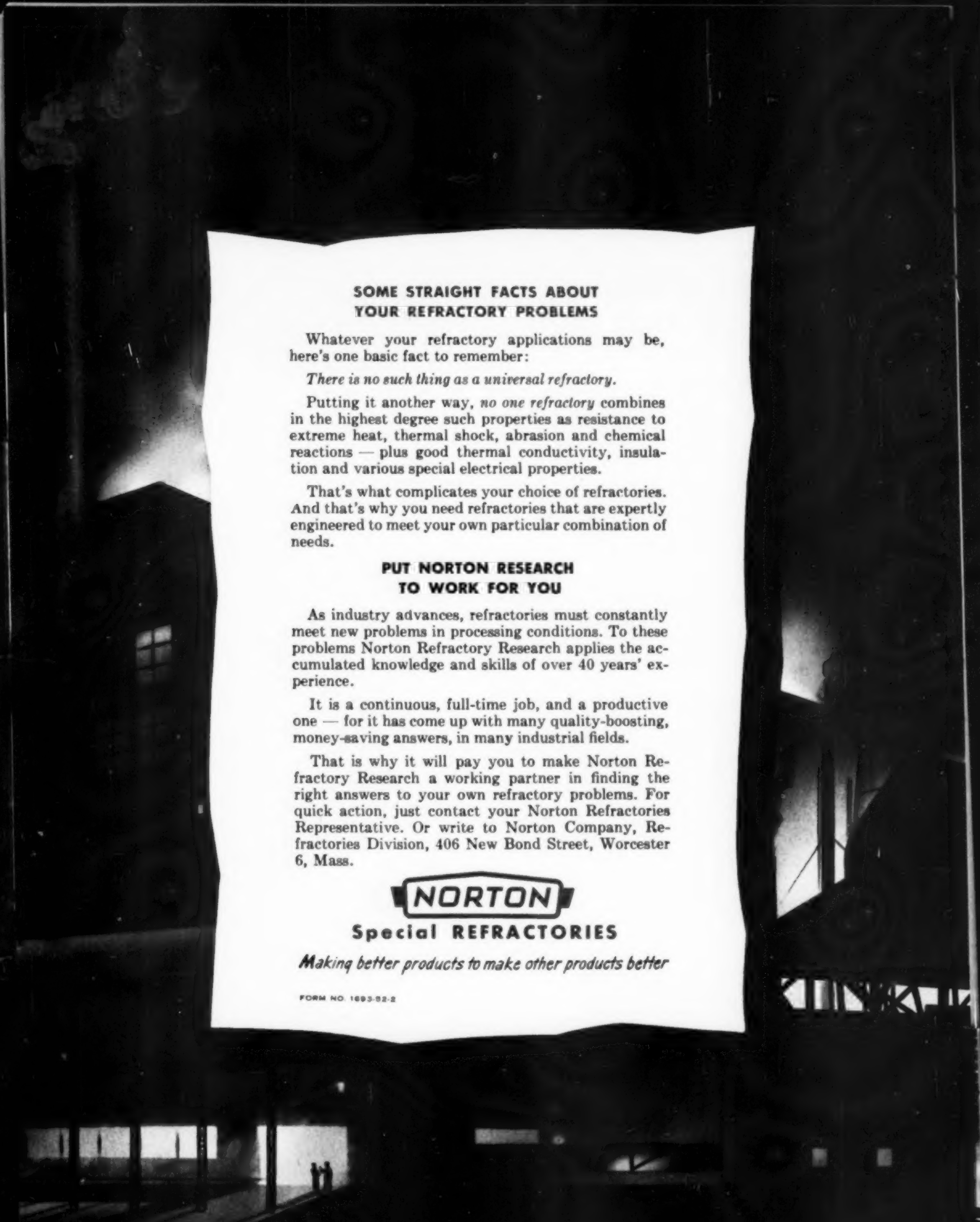
LET'S TALK IT OVER.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

THIS DESULPHURIZING LADLE was lined with a special Norton ALUNDUM refractory cement which outlasts other refractories as much as four to one.

THESE NORTON CRYSTOLON SHAPES, according to independently conducted ASTM tests, equal or surpass in thermal conductivity any other silicon carbide shapes in use today.





SOME STRAIGHT FACTS ABOUT
YOUR REFRACTORY PROBLEMS
Whatever your refractory applications may be, here's one basic fact to remember:
There is no such thing as a universal refractory.
Putting it another way, no one refractory combines in the highest degree such properties as resistance to extreme heat, thermal shock, abrasion and chemical reactions — plus good thermal conductivity, insulation and various special electrical properties.
That's what complicates your choice of refractories. And that's why you need refractories that are expertly engineered to meet your own particular combination of needs.
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As industry advances, refractories must constantly meet new problems in processing conditions. To these problems Norton Refractory Research applies the accumulated knowledge and skills of over 40 years' experience.
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Metal Progress

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The Use of Castings in Airframe Design

By A. H. Petersen, Los Angeles, Calif.*

Airplanes are getting heavier. They are getting heavier because of a considerable advance in performance during the past few years. Airplanes flying at high Mach numbers, approaching and even past the sonic barrier, are subjected to peculiar aero-elastic loads which make the proper distribution of mass in their structure of vital importance. Structures whose static strength is adequate must be "beefed up" to meet the required torsional rigidity and to avoid undesirable flutter. "Bits and pieces" design is fast becoming outmoded because undesirable flying characteristics can often be traced to slippage at joints. Consequently, materials having high strength-weight ratios are more and more widely employed in airframe structures; furthermore, the size of the various individual components is increasing.

Recently, there has been much conversation regarding the use of castings in airframes, be they sand or permanent mold or castings produced by specialized modifications of the basic processes. It has been implied that airframe designers have neglected this important class of constructional materials. Nothing could be further from the truth. Casting processes, like all others used in the airframe industry, have their particular scope and place; the casting's place lies in the field of intricate configuration where it is advantageous to combine several units into one, or where highly cyclic loading can be avoided and where their strength is such that undue weight penalties will not be incurred.

It has often been stated that forgings, plate, sheet and other wrought products begin life as cast ingots and that the quality of the wrought product is dependent on the quality of the ingot. This is true; however, the simple statement requires qualification. No amount of subsequent extruding, kneading, upsetting, blocking, forging or rolling will remove all the defects found in an unsound ingot. Thus, the so-called "unhealed porosity" in aluminum alloy forgings can be traced to stringers or oxide inclusions occurring in the ingot. But to say that such a situation is the rule is unjust and takes credit away from the men constantly seeking to improve present-day techniques. We have yet to see the like of the typical forging or extruded structure in any cast aluminum product selected at random from typical production runs of today.

Consequently, the reference to the cast ingot as the origin of wrought products should be restated in some such words as these: Starting with a sound ingot (which must be the premise), subsequent working improves properties to a degree not attainable by the simple process of pouring hot metal in a mold, regardless of the controls employed.

While much has been made of the fact that certain aluminum casting alloys have been found which on testing have a tensile strength on the order of 70,000 psi., such properties do not exist in production lots today. It is a well-known fact that an aluminum alloy with 4.5% copper-containing additions will possess, in the wrought and heat treated state, a hardness of over 110 Brinell and a tensile strength of 60,000 psi., but the same alloy, as cast, after hardening by heat treatment will not develop much over 60% of this strength.

Table I gives the strength values for various wrought and cast alloys in Specification AN-C-5 of the Departments of the Navy, Air Force and Commerce and now employed in the airframe industry. Included is 78S, the newest wrought alloy being tested today, but for which design allowables are not yet established. The spread between tensile strength and yield strength of the wrought materials as compared with the cast materials in this table strikingly illustrates a point.

ACCEPTANCE TESTS FOR CASTINGS

The aircraft industry probably makes static tests on more castings than on any other components of airframes, destroying

*The author, member of the Los Angeles Chapter ⊕, was for ten years production design engineer with Lockheed Aircraft Corp. Three years ago he also became Lockheed's representative on the Aircraft Research and Testing Committee (Western Region) of the Aircraft Industries Assoc. Since this article was written he has joined the Harvey Machine Co. to work on the Heavy Press Program (large forgings and extrusions) of the U. S. Air Forces. Acknowledgment is made to George W. Papen of the Lockheed Aircraft Corp. for permission to use illustrations.

Static Testing and Flaw Detection

three castings of the first production lot of each critical casting for an Air Force plane. In addition, standard test bars are pulled for each production lot of castings to determine if the lot meets specification values (which are founded on experience and on countless tests). It can be assumed that if these tests on castings, made in typical foundries throughout the country, should consistently show higher values than those of the specifications, these last would have been raised.

Some engineers take issue with the test-bar method of evaluating the strength of production lots of castings. If very careful attention is not paid to risering and chilling, they have a point, since a section out of a ¼-in. web may very well give a better value in tension than a ½-in. test bar.

Aircraft castings are subjected to rigid radiographic tests and examination by fluorescent or magnetic penetrant to detect flaws. Rejections in the product of one foundry which I am acquainted with are running less than 5% monthly. This is not to say that foundries do not suffer a higher rejection rate due to various reasons which have nothing to do with molding, pouring or heat treating. Improper snagging, excessive grinding of flash, improper location of part numbers, wrong identification, and dimensional errors cause the bulk of the average foundry's rejections. These are due to personnel problems and are experienced today not only by foundries but by all other types of fabricators, including the airframe industry itself.

A number of airframe companies have established radiographic standards showing acceptable and unacceptable internal defects. Similar standards have recently been published by the Bureau of Aeronautics. Such standards have been used for many years and have served to establish a common ground of understanding, thus reducing casting rejections, and assisting foundries through a uniform interpretation. In more or less degree, the defects shown on X-ray negatives are fairly common in castings produced in static sand and permanent molds. Porosity, microshrinkage, gas holes and the like can be controlled. Whether they can be eliminated entirely is yet to be proved.

Recently, the airframe companies on the West Coast, through the Aircraft Research and Testing Committee and the Aircraft Inspection Committee of the Aircraft Industries

Table I — Minimum Tensile Properties of Aircraft Materials
(Specification AN-C-5)

Material	Ultimate	Yield	Elongation in 2 In.
Wrought Aluminum Alloys (Bare)			
24S-T4	62,000	40,000	8%
75S-T6	77,000	66,000	8%
78S	84,000	73,000	8%
Aluminum Sand Casting Alloys			
195-T6	32,000	20,000	3%
356-T6	30,000	20,000	3%
220-T4	42,000	22,000	12%
Magnesium Sand Casting Alloys			
AZ63-T6	34,000	16,000	3%
AZ91A-T6	34,000	16,000	3%
Alloy Steel, Wrought and Heat Treated			
4340	260,000	240,000	10%
8630	125,000	100,000	17%
8740	180,000	165,000	12%

Assoc., have proposed that the continual static testing of castings be eliminated and replaced by the controlled analysis of casting defects on a statistical basis.

In addition to this common-sense approach to control, it is now general practice to indicate on drawings the critical areas of the part, the direction of loading, and otherwise direct the foundryman's and inspector's attention to the important considerations.

REQUIREMENTS FOR USE IN AIRFRAMES

A number of airframe factories normally employ factors of 1.25 or 1.33 in stressing aluminum and magnesium alloy castings. That is to say, if the part is a casting, the designer increases the loads by one quarter or one third, and this factor, incidentally, is one reason castings often fail to compete weight-wise with sheet metal assemblies. This factor has steadily decreased over the past few years, due to the constant efforts of engineers and foundrymen to improve design and technique. Today, many stress engineers contend that complex castings need no factor but should be treated like any other type of indeterminate structure and statically and dynamically tested only so far as is necessary to determine performance under load.

As strength requirements go up, however, the casting finds it more and more difficult to compete with the wrought alloys. This is strikingly true of steel alloys and consequently they are not widely used in the cast

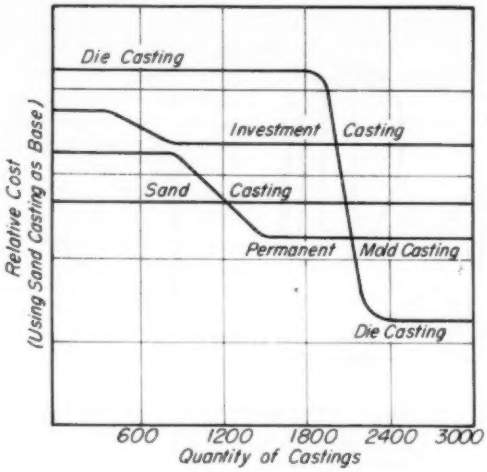


Fig. 1 — Relation Between Cost and Quantity of Castings, Machined Ready for Use, Indicating the Approximate Break-Even Point for Four Important Casting Methods — Sand, Investment, Die Casting and Permanent Mold

form in airframes today. In contrast, consider the tons of castings used in other industries which are of fairly heavy section and are used as-cast, normalized or moderately heat treated. With weight as his criterion, the average aircraft engineer will design a casting with widely varying sections and then demand a heat treatment to give an ultimate strength on the order of 200,000 psi. or better. These are hard to produce successfully, for minute surface cracks occurring on shrinking in the mold and heat checks traced to severe quenching are an invitation to fatigue failure in service. Small wonder the aircraft industry gets the fishy stare from the tonnage foundry and decides to stick to machined parts of wrought stock which can be heat treated to 300,000 psi. ultimate strength.

Again, where ductility or ability to take deflection is of prime importance, the casting takes a beating. After heat treatment, it is a rigid and unyielding member. Tied to sheet metal structures which work close to their yield stress, the casting's inability to "work" or deflect may cause early failure. True, "tri-laminar" structure of the casting gives it equal properties in all directions, but who would rather load a 75S-T6 forging in the transverse direction when he can take advantage of its much higher properties in the longitudinal direction?

All this is not to say that castings have no place in aircraft. There are a considerable number of castings of all types, configuration and size, of various aluminum and magnesium alloys, employed in structures of primary and secondary importance and for pressure vessels, valves and fittings, and wherever else they can be used economically and to save weight. This is shown in Table II.

Table II — Average Quantity of Castings of All Types in Airplanes

	1949	1950	1951
Transport	525 lb.	514 lb.	479 lb.
Bomber	702	658	637
Fighter	154	184	198
Trainer	—	164	177

MOLDING METHODS

The majority of the castings now used in airplanes are cast in sand molds because quantities do not generally justify the cost of permanent molds or other specialized processes. These are normally used when considerable machining can be eliminated or for pressure vessels. Die castings are attractive where dimensional accuracy is more important than structural properties. Figure 1 illustrates the point that *number* of castings required to a given design has a considerable bearing on the molding process. (Incidentally, the only machining the normal sand casting gets is on mounting pads, bores and attachment or bolt holes.)

Much publicity has recently been given the "advanced" casting processes and techniques which may provide greater dimensional accuracy and soundness, yet it is the present writer's belief that sand castings are being produced today which are every bit as accurate and sound as required by the airframe application. As-cast mating and attaching faces are employed wherever the elimination of machining costs justifies the added expense of obtaining such smooth, no-draft surfaces. Precision metal patterns are used for aircraft castings as a general rule.

Paying $4000 to $10,000 for precision patterns for typical components weighing on the order of 6 to 20 lb. or for specialized metal or ceramic molds, or for the use of specialized equipment for controlling pressure and temperature

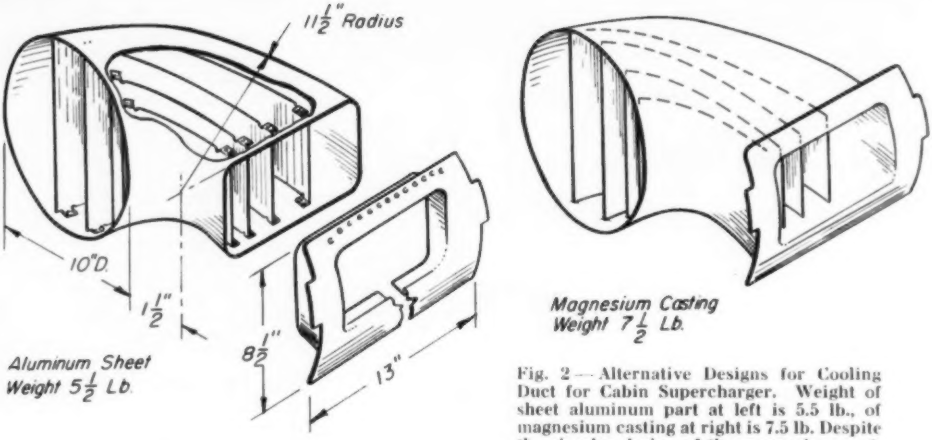


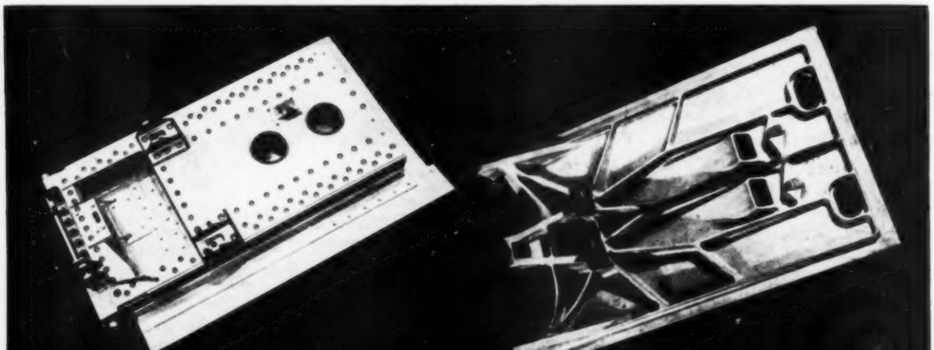
Fig. 2 — Alternative Designs for Cooling Duct for Cabin Supercharger. Weight of sheet aluminum part at left is 5.5 lb., of magnesium casting at right is 7.5 lb. Despite the simpler design of the magnesium casting, this duct cannot be cast in production because of unsolved shrinkage problems

in the mold, must certainly be justified on a sound economical basis. Yet the industry is continually paying such costs — often merely for the advancement of the art.

The writer has been privileged to study many of the latest advanced casting processes and techniques, the Croning or shell molding process, the Parlanti, the Wessel, the Mercast, the Bacco, the Osbrink, the Permafuge and others. Each of these constitutes a step forward; each has decided limitations of source, cost or size, or has not advanced to become generally accepted as a production process.

Some Current Problems in Substitution — Aircraft designers are intensely aware of the advantages of casting large, intricate and accurate components as a single part, within the inherent limitations which set castings apart from hot and cold worked metals. Castings will continue to be employed as widely as these limitations permit. Improvements in casting techniques will continue to refine structures, reduce porosity and microshrinkage, and may some day increase the physical properties of standardized alloys. Far from ignoring the foundry, it has been through the demands of the aircraft engineer, the time he has spent in research, the controls set up due to his demands, and the willingness of

Fig. 3 — Wing Upper Surface Structure and Aft Section of Dive Flap for Fighter as a Sheet Metal Structure and as Successfully Replaced by a Magnesium Sand Casting. The area is approximately 16 x 26 in.



foundries serving the industry that marked advancements are being made. The following illustrations will attest to this fact and point the reasons for continued effort.

Figure 2 compares ducts made of sheet metal and of a single casting. This duct cannot be cast in production because of unsolved shrinkage problems, yet it should be noted that it weighs 2 lb. more than its sheet metal counterpart. It is no cheaper to produce, despite the elimination of three dies and two welding fixtures, because of the difficult coring problems and the special techniques required to obtain uniform metal flow throughout the very thin structure. The 0.10 in. required for the casting is double the thickness of the 0.051-in. 3S-O aluminum alloy sheet in the current design. This is a typical example of one very important reason why castings are not more generally employed in aircraft.

In Fig. 3 are shown alternative designs of a dive flap for a fighter. The pattern alone for the magnesium sand casting cost \$1750, the casting, \$85 per copy. A permanent mold for this casting cost over \$8000, but to date this permanent mold has not produced a satisfactory casting, despite ten months' time and labor. A glance at the sheet metal structure replaced by the sand casting indicates why the latter was justified.

The D-tube casting for the leading edge of an elevator for a fighter airplane is shown in Fig. 4. This 356-T6 aluminum sand cast-

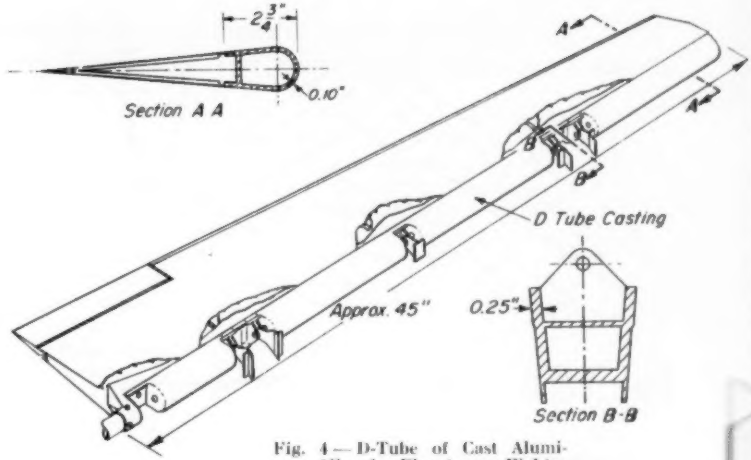


Fig. 4 — D-Tube of Cast Aluminum Alloy for Elevator on Fighter

ing just meets the weight of the sheet metal structure — 11.78 lb. If the portion aft of the D-tube were attempted as a casting, problems of metal flow would dictate a web thickness which would increase the weight over the combination shown by approximately 3 lb., and the tooling cost would be out of this world.

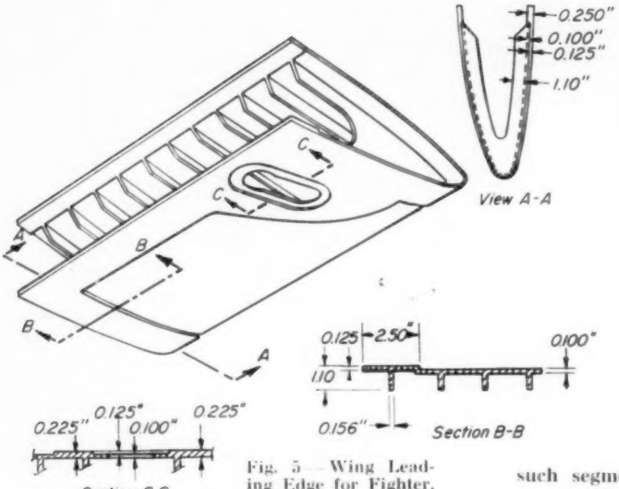


Fig. 5 — Wing Leading Edge for Fighter. Magnesium AZ91 sand casting, not heat treated. The finished weight is 7.4 lb. — about equivalent to a sheet metal component

Figure 6 shows an experimental air duct segment, of approximately 18 x 32-in. opening, whose development cost more than $3000. The fighter airplane for which it was intended employed two ducts, each requiring three such segments. If they could have been successfully cast it would have saved close to $250,000 in detail sheet metal tooling. The casting was not used because of the difficulty of maintaining the 0.100-in. wall in production. Sadly enough, this casting met twice the pressure requirements.

A sand casting can replace a sheet metal structure, as is illustrated by the wing leading edge of Fig. 5. This casting is equivalent in weight to a sheet metal component — and could well be even lighter.

Advanced types of design such as these are the aim of the airframe industry and will become more and more prevalent as research continues and costs become more realistic. Evolution is inevitable and it only requires a more concerted effort on the part of designers and founders alike to hasten it.

It should go without saying that the aircraft designer will use every available tool to reduce weight and production costs. Advances to date within the sphere of his activity are directly traceable to his demands for better and stronger products. If castings are to become more widely used, their quality must improve in like degree and they must become more uniform from lot to lot. The emphasis will then be on more rigid controls rather than on relaxation of current controls. Demonstration will engender confidence. Once this is achieved, the casting industry will be busier than ever before.

Fig. 6 — Cast Segment for Air Inlet Duct Which Could Not Be Produced Commercially to Required Limits of Wall Thickness: 0.100 In.

By Walter L. Finlay, Research Manager, C. I. Bradford, Director of Operations,
and G. T. Fraser, Sales Manager, Rem-Cru Titanium, Inc., Midland, Pa.

The ABC of Titanium Alloys

The ABC viewpoint appears to be an excellent way for both the titanium specialist and the occasional user to scan the field and examine his titanium problems in convenient and useful perspective. The ABC's of titanium alloys are alpha, beta and combined alpha-beta. Also, D for detrimental might be applied to eutectoid third phases and excessive amounts of carbides. These and the rest of the alphabet will undoubtedly be used over and over again in the decades to come to explain the complexities of titanium metallurgy. Somewhat oversimplified, however, the trio of alpha, alpha-beta and beta can be used to describe the general features of all past, present and foreseeable titanium-base alloys.

The last statement may seem to be a bit too all-encompassing for any single generalization. Nonetheless it is fortunately true that many of titanium's complexities may be rather simply systematized.

Figure 1 presents a basic phase diagram for titanium-base alloys and illustrates the fundamental facts of the ABC viewpoint. These fundamentals are that titanium transforms from hexagonal alpha to body-centered beta at 1625° F.; and that increasing amounts of many of its common alloying elements progressively drop the lowest temperature at which the structure is entirely body-centered until, finally, it possesses that structure well below room temperature. Thus the titanium metallurgist has three basic alloy types with which to work: alpha, beta and combined alpha-beta.

Industrial activity to date in the titanium alloy field has been concerned almost entirely with alpha-beta alloys (see "Titanium Alloys Today", by Walter L. Finlay and Milton B. Vordahl, *Metal Progress*, February 1952). These have a medium alloy content in the range of 3 to 9% and have firmly established themselves as one of the foundation blocks of the structural titanium alloy industry.

Table I includes the properties of two such alpha-beta alloys and gives the typical room-temperature mechanical properties of one current line of standard titanium-base products.

The foregoing comprises, as one group, two grades of commercially pure titanium, RC-55 and RC-70; and, as a second, two types of alpha-beta alloys, RC-130-A and RC-130-B. Both groups have been described in considerable detail in the past. Also, it seems today, both will continue to be of real utility for a long time to come. But it is equally likely that they will be supplemented by all-alpha and all-beta alloys.

The terms alpha, beta and combined alpha-beta have more than purely crystallographic significance. They are the best capsule characterizations of the general mechanical properties of the alloys. Thus:

A is alpha, for all-round performance (good weldability, strong both cold and hot and against oxidation but a bit muscle-bound in bending).

B is beta, for bendability (excellent bend ductility, strong both cold and hot, but vulnerable to contamination and a big consumer of strategic alloys).

C is combined alpha and beta for compromise performance (strong cold and warm but weak hot, good bendability, moderate contamination resistance, and excellent forgeability).

Table I — Room-Temperature Mechanical Properties of Titanium and Titanium Alloys

Property	RC-55 Sheet	RC-70 Sheet	RC-130-A Sheet	RC-130-B Rolled Bar
Ultimate Tensile (1000 psi.)	75	90	130	150
Yield (1000 psi.)	65	80	115	140
% Elongation	25	20	15	18
% Reduction in Area	—	—	—	40
Proportional Limit (1000 psi.)	50	65	95	105
Bend Ductility (T)	1.5	2.0	2.0	—
Chemical Composition	Commercially Pure		8% Mn	4% Mn, 4% Al

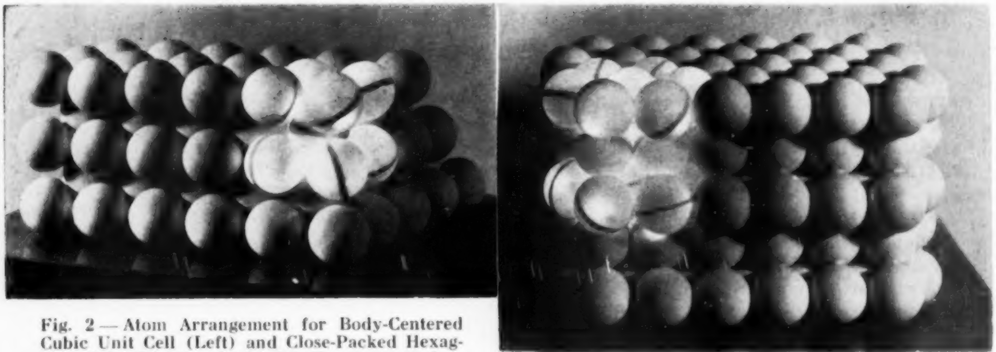


Fig. 2 — Atom Arrangement for Body-Centered Cubic Unit Cell (Left) and Close-Packed Hexagonal Cell (Right). Lighted balls correspond to the atoms in the diagrams. (From Ⓜ Tech Book, "The Nature of Metals", by Bruce A. Rogers)

A good part of this summary is shown in Fig. 3 in graphical form. When examined in detail it emphasizes that the significant strength-weight advantage of titanium over other structural metals varies with temperature; more pertinent to the present discussion, that there are very important differences in the temperature dependency of the properties of titanium-base alloys depending upon whether their crystal structure is alpha, or beta or combined alpha-beta. The practical significance of the ABC criteria is particularly evident upon studying the data in this graph.

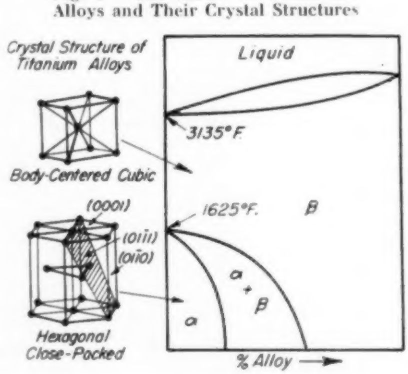
The outlines of the alpha, alpha-beta, beta framework are shown in Fig. 1. Only the most pertinent features will be briefly discussed here although, to one concerned with the why and how of plastic deformation, the crystal mechanics of metal flow in titanium and its difference from that of other metals present a fascinating study.

Both the hexagonal and the body-centered structures are very familiar to the metallurgist and he entertains some fixed notions about each. Probably the most prevalent is that the hexagonal structure "hexes" plastic deformation.

This concept is logically and historically based on the behavior of hexagonal metals such as magnesium, cadmium and zinc. In these three metals the basal planes are the key performers during deformation. This can be readily appreciated from Fig. 1 and 2 in which a particular basal plane designated (0001) is shown. The triangle of atoms in the center and the hexagonal array of atoms at the bottom of the hexagonal space lattice in this figure are also basal planes. Geometrical consideration will show that, in a hexagonal close-packed structure of spheres, the basal planes are more widely separated than any other set of parallel planes; moreover, the basal planes have the densest grouping of atoms. Therefore, when a hexagonal metal such as magnesium is deformed, the basal planes tend to act like cards in a deck and slip occurs by one basal plane sliding over another.

A deck of cards cannot conveniently be pushed into many shapes, whereas a handful of clay, which can slip in all directions rather than merely between one set of parallel planes, can readily be pushed into any shape. Similarly, a conventional hexagonal metal cannot slip conveniently — which is to say, without its fracturing — in as many directions as can a body-centered cubic or a face-centered cubic metal. Hence the soundly-based idea that the hexagonal structure "hexes" plastic deformation or, more specifically, that basal slip implies rather limited ability to react favorably to applied stresses, par-

Fig. 1 — The ABC's of Titanium Alloys and Their Crystal Structures



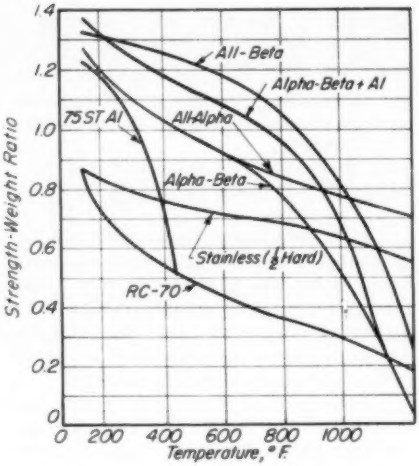


Fig. 3 — Ultimate Strength-Weight Comparison as a Function of Temperature of All Titanium-Base Alloys in Comparison With 75ST Aluminum and Stainless Steel

ticularly bi and tri-axial loading. Also, basal cleavage suggests low toughness, especially below room temperature.

As befits its status as middleweight champion* of the structural metals, however, titanium's alpha hexagonal structure is not subject to such disabilities. Its axial ratio of 1.59 (the ratio of height to width of its unit cell) is well below the 1.63 characteristic of the close-packed spheres (Fig. 1 and 2) and illustrative of, for example, magnesium. This difference apparently has a profound effect on the modes of deformation and fracture of alpha titanium and probably accounts for its surprisingly good ductility and toughness.

The significance of the 1.59 ratio can be envisioned in Fig. 1 by picturing the spherical atoms as flattened to ellipsoids. The basal planes then no longer possess the greatest atomic density. According to Rosi, Dube and Alexander ("Mechanism of Plastic Flow in Titanium", *Journal of Metals*, Vol. 4, 1952) slip in alpha titanium does not occur to any very appreciable extent on the traditional basal planes but does on the prismatic $(01\bar{1}0)$ and pyramidal $(01\bar{1}1)$ planes shown in Fig. 1.

The feature which alpha titanium does have in common with traditional hexagonal deformation (and in fact with that of all metal crystals) is that the direction of slip between parallel planes is along the rows of

No "Hex" in Hexagonal

close-packed atoms. In the hexagonal structure, these are common to the basal, prismatic and pyramidal planes. Examples of these close-packed rows are the sides of the basal plane hexagons shown in Fig. 1. These comprise three directions. These plus three families of planes (prismatic, pyramidal and basal) constitute a deformation system that is more versatile (and therefore more ductile) than that of the basal alone.

The body-centered cubic structure is, as previously indicated, still more versatile than that of alpha titanium. Like the latter, it slips in the direction of one of its close-packed rows of atoms. But there are four such in the body-centered structure. These are the diagonals of the cube shown in Fig. 1. As a result of this versatility in plastic deformation, beta titanium exhibits better ductility under complex stresses than alpha.

Thus, for example, at any given strength level the bend ductilities of alpha alloys are considerably poorer than are those of beta compositions. A fabricator can easily impart to an alpha alloy the superior bending properties of a beta alloy simply by raising the temperature several hundred degrees — the higher the better, up to a maximum of perhaps 1000° F.

"Simply" is, however, a deceptive term to apply to this expedient when hot forming equipment is either not available or not feasible. In such situations, a beta alloy has an important advantage over an alpha alloy. Also, an alpha-beta alloy has an important advantage over an alpha composition. The bend ductility of an alpha-beta alloy reflects, roughly, the proportions of alpha and beta present — the more beta, the better the bend. In an alpha-strengthened (and correspondingly, therefore, alpha-embrittled) alpha-beta alloy, the presence of some beta cannot make up for the alpha's bending deficiencies and the bend ductilities are closer to those of an all-alpha. RC-130-A is an alpha-beta alloy with unstrengthened alpha and is one whose good bend ductility recommends it for sheet forming operations. RC-130-B is an alpha-strengthened alpha-beta whose poorer bend ductility excludes it from some sheet applications but whose better hot strength fits it for plate, bar and forgings

*Based on its intermediate density and stiffness in combination with its strength which matches that of alloy steel.

where bend is not so predominant a factor.

One additional important characteristic in the crystal mechanics of titanium alloys merits mention. That is the relatively low strength of the two-phase alpha-beta alloys at temperatures above 600° F. relative to the single-phase all-alpha or all-beta alloys. On the debit side, this means lower yield and creep strengths for the alpha-betas in the important service temperature range of 600 to 1000° F. On the credit side, it means easier forging and rolling in the important hot forming range of 1200 to 1800° F.

TEMPERATURE EFFECTS

The explanation for the lower hot strength of the two-phase alloys is contained in Fig. 1. Its phase diagram shows that, as the temperature is raised or lowered, the proportions of alpha and of beta change. Transformation of alpha to beta and vice versa is accomplished by shearing movements of atom planes and these are similar to slip movements. During any hot working operation, temperature changes will initiate these shearing movements. These cooperate with external stresses to cause slip and the net result is lower strength.

Forging — These crystal structure considerations apply also to the temperature ranges employed for forging but other factors must be considered as well. Generally, forging temperatures of the various alloys are a compromise between the increased plasticity of higher temperatures and the decreased oxidation of lower temperatures. Both these factors are importantly affected by the crystal structure of the alloy — plasticity as previously indicated, and oxidation by the fact that beta is more vulnerable to oxidation than alpha. And the oxidation resistance of a particular crystal structure may vary with its alloy content; for example, the aluminum in RC-130-B permits higher forging temperatures than those used for RC-130-A. Thus:

Alloy Type	Forging Range
Alpha	1900 to 2000° F.
Alpha-Beta	
RC-130-A	1600 to 1750
RC-130-B	1650 to 1800
Beta	1600 to 1700

Up to this point, the emphasis has been on crystal mechanics. This emphasis is well deserved because of the controlling importance it plays in the industrially interesting properties of titanium-base alloys. Of complementary importance, however, are the effects of the various alloying elements.

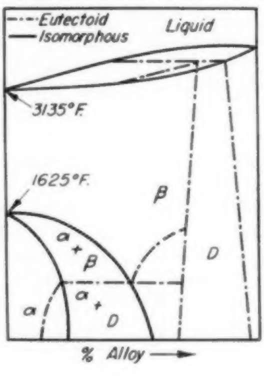
One group of elements promotes (that is, stabilizes over a wider temperature range) the alpha form. This group includes carbon, oxygen, nitrogen and aluminum. A second group stabilizes the beta form and includes hydrogen, manganese, chromium, molybdenum, iron, vanadium, and columbium.

The beta-isomorphous★ diagram of Fig. 1 is the basic one for the beta stabilizers. It applies, for example, to the Ti-Mo and Ti-V systems. In a number of other important beta binaries, however, a eutectoid reaction may insinuate itself as indicated in Fig. 4. Ti-Mn, Ti-Cr and Ti-Fe are examples of this. The third phase introduced by such eutectoid reactions may cause damaging embrittlement although in many cases this reaction is so sluggish that it appears to be inoperative in hypo-eutectoid compositions such as the 8% Mn and the 4% Mn, 4% Al alloys.

In hyper-eutectoid compositions such as many of the unstable betas, however, eutectoid third phases are undesirable aliens as will subsequently be discussed.

The alpha stabilizers raise the transformation temperature range and so are characterized by terminal peritectoid phase diagrams. All-alpha alloys are examples of this type. But when alpha stabilizers are added to a beta-stabilized titanium base, the usual effect is that the alpha stabilizer concentrates in and strengthens the alpha phase while the beta stabilizer

Fig. 4 — Causes of Embrittlement Are: Segregation During Freezing; Contamination; and Heat Treatment During Which Unstable Beta Transforms to Either Alpha, or to Alpha and a Third Phase (D)

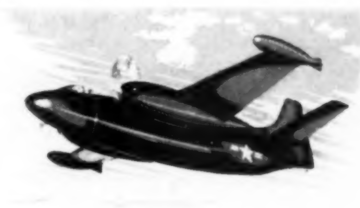


★The term beta-isomorphous means that the same beta form of crystal structure extends from the 100% titanium boundary over a composition range to room temperature.

concentrates in and strengthens the beta phase and the equilibrium relationships remain beta-isomorphous in character. The metallurgist thereby has considerable latitude in tailoring alpha-beta alloys to particular requirements.

This versatility was previously touched upon in referring to RC-130-A and RC-130-B. The former is a binary 8% Mn alloy with essentially unstrengthened alpha. This results in better bend ductility but poorer hot strength than those possessed by an alpha-strengthened alpha-beta such as RC-130-B (4% Mn, 4% Al). Aluminum not only significantly raises the hot strength but it also improves forgeability by raising the maximum forging temperature, cooling rate and number of reheats.

Very large additions to titanium of a beta-stabilizing alloying element such as molybdenum result in a completely stable beta alloy. By completely stable is meant one which remains, regardless of thermal and mechanical treatment between room temperature and the melting point, entirely beta. Thirty or more per cent of molybdenum in titanium achieves such an alloy but at the expense, of course, of increased density.



Between the very large beta-stabilizing additions of the stable beta and the medium additions of the alpha-beta alloys is a region in which the alloys quite readily retain the beta structure in an unstable form, even on air cooling. However, several hours to several days at temperatures in the range from 300 to 800° F. permit some of this unstable beta to transform, often accompanied by embrittlement. Thus beta alloys can be classified as either unstable or stable.

Table II — Classification of All Structural Titanium-Base Materials

1. Unalloyed Titanium
   a. High commercial purity (RC-55)
   b. Commercial purity (RC-70)
2. All-Alpha Alloys (binary Ti-Al)
3. Alpha-Beta Alloys
   a. Binary (RC-130-A; 92% Ti, 8% Mn)
   b. Alpha-strengthened (RC-130-B; 92% Ti, 4% Mn, 4% Al)
4. Beta Alloys
   a. Unstable (85% Ti, 15% beta stabilizers*)
   b. Stable (65% Ti, 35% Mo)

*Beta stabilizers are alloying elements such as Mn, Cr, Mo and Fe.

The foregoing provides a framework for placing all titanium-base structural materials in common perspective. From this viewpoint, they can be classified as in Table II.

The introductory paragraphs indicated that the pioneering work to date in titanium had been conducted with Class 1 and 3 material; moreover, that, as more difficult and specialized requirements were placed on the titanium industry, the all-alpha and all-beta alloys would gradually be introduced and used. To assist this introduction and utilization, the advantages and disadvantages (to the extent that they are currently known) of each alloy type are summarized in Table III.

All-alpha alloys accordingly appear to have a large future for a wide variety of products requiring good oxidation resistance, hot strength and weldability. As previously indicated, the alpha-beta alloys are presently and probably will long continue to be regarded as the wheel horses of the titanium stable.

More stylish and more skittish members of the latter are the stable and unstable beta alloys. As indicated previously and as outlined in Fig. 4, this instability can arise from at least two different reactions.

The first of these is the transformation of some unstable beta to alpha. This can occur in the beta-isomorphous type shown by the solid lines in Fig. 4. This reaction is promoted by alpha stabilizers like the omnipresent oxygen and nitrogen. The second is the previously discussed eutectoid reaction shown by the dotted lines (Fig. 4). In this case, the third phase (designated D) is the embrittling agent.

The stylish feature of the beta alloys is their excellent bend ductility at quite high strength levels — zero T bends at 150,000 psi. tensile and higher are quite possible in laboratory samples.

The skittish feature of the beta alloys is their instability which manifests itself by

Evaluation of Types

changing a strong, ductile, tough material of construction to a dangerously glass-brittle condition. Properly controlled, this tendency might be quite usefully employed. Such control is difficult, however, since instability can be triggered by small changes in chemical composition, the presence of contaminants and changes in thermal and mechanical processing.

The unstable and stable beta alloys clearly have important roles to play where the combination of the highest strength and bend ductility is required. But, due to the ever-present possibility of embrittling instability, consideration of their use should proceed with caution and should be accompanied by thorough simulated and actual service condition tests.

The foregoing summaries highspot the good and bad features of the several titanium alloy types. These summaries do not permit any detailed comparisons. Indeed, many of the necessary details have yet to be determined. And, in fact, the efforts of several generations of metallurgists will doubtless be required to dispel the unknowns so that titanium metallurgy will be an open book from A to Z. Meanwhile it is hoped that the ABC's of titanium alloys will be a useful framework within which to place and to relate much of the welcome but ever-increasing flood of titanium data which is pouring forth at a rate unmatched by that of any other new metal.

Table III — Characteristics of Titanium Alloys

Type	Advantages	Disadvantages
All-Alpha	Useful strength to almost 1200° F. Resistant to air contamination to 2000° F., thereby permitting higher forging temperatures. No embrittling heat treatment response. Good weldability.	Sheet bend ductility not as good as that of alpha-beta alloys and considerably poorer than that of beta alloys. Requires more power for hot working than alpha-beta alloys.
Alpha-Beta	Double the strength of unalloyed titanium and about as strong below 400° F. as all-alpha and all-beta. Good ductility, including bend. Forging, rolling and forming easier than alpha and beta alloys (beta has better bend ductility). Relatively simple to produce in quantity. Heat treatable to high strengths.	Has heat treatment response which, if not controlled, results in loss of ductility. Poorer weld ductility than alpha. Temperature ceiling for useful strength about 800° F.
Unstable Beta	Quenchable to give medium strength with high ductility. Can be heat treated to higher strength (with some loss in ductility) after fabrication. Elevated-temperature properties similar to alpha-beta alloys.	Embrittled by 24 to 96 hr. at 350 to 800° F. Control of composition critical. Restricted to parts that can be heat treated after fabrication, or parts that require little forming after heat treating. Requires relatively high content of strategic alloying materials.
Stable Beta	Excellent ductility, particularly bend. High strength useful to approximately 1000° F. Does not require heat treatment for high strength. No heat treatment response. Good weldability with some compositions.	Very sensitive to contamination during production. Sensitive to contamination in air above 1300° F. Greater springback in forming. Uses higher content of strategic alloying materials than unstable beta.

By Henry H. Hausner, Manager of Atomic Energy Engineering
Sylvania Electric Products Inc., Bayside, N. Y.

Austria Is Host to World Congress on Powder Metallurgy

The importance of powder metallurgy, its value as a research tool and its recognition as a production method are best characterized by the fact that three technical and scientific meetings on powder metallurgical subjects were held in Europe in June 1952.

The Fourth International Mechanical Engineering Congress was held June 4 to 10 at Stockholm, Sweden, with an interesting session on powder metallurgy, the papers of which were presented mainly by Swedish and German engineers. The International Symposium "On the Reactivity of Solids" was held June 9 to 13 in Gothenburg, Sweden, with 82 papers presented by engineers and scientists of 19 countries. Most of these papers were of a theoretical nature, dealing with the reactivity in the solid state, and 15 of these papers concerned the application of this reactivity in the powder metallurgy process of sintering. The Plansee Seminar, "De Re Metallica", was held June 22 to 26 in Reutte (Tyrol), Austria. This meeting had a certain similarity with the Gothenburg symposium, but special emphasis was given to powder metallurgy in a large majority of the papers. The bulk of the present article consists of a brief review of this meeting.

The European Industry — The present reviewer, who attended all three meetings, obtained a certain insight into European powder metallurgy and especially into its research and development phase. Before the war, the center of powder metallurgy research was in Europe, whereas the center of production was in the United States. This condition has changed considerably during the last few years. More basic research and development is now done in the U.S.A. than all the European countries together, whereas Europeans are more production-minded than ever before. The reason for this switch is mainly financial. (It can also be observed in other branches of science and technology.)

There are not enough funds available in most of the European countries for doing high-class, fundamental research work. The laboratories of the government-owned European universities were largely destroyed during the war and have not yet been rebuilt entirely, nor are they adequately equipped. The salaries in the universities are low and unattractive. Most of the privately owned industries were also destroyed during the war but were rebuilt in a surprisingly short time. These industries are mainly interested in short-term development programs which permit a large-scale production; fundamental research is therefore neglected.

This should not be interpreted to mean that good research work is not being done in Europe. In view of all their difficulties, the work is admirable. The center of European basic research work in powder metallurgy lies in Austria and Germany. G. F. Huettig and A. Smekal of the University of Graz are still pioneers in the field, and a new Austrian generation of scientists with E. Onitsch-Modl (Leoben) and Novotny (Vienna) is doing outstanding basic work. German scientists such as W. Jost, W. Koester, G. Masing, G. M. Schwab, W. Seith, F. Skaupy and I. N. Stranski are leading in the field of solid state physics as applied to powder metallurgy.

Powder metallurgy as a production method is widely practiced in England, Sweden, Austria and Germany. In Italy, France and Spain it is still in the development stage.

A new powder metallurgical method for making continuous sheet and strip from brass and iron powder was developed by Dr. Naeser (Germany). Metal powders are pressed between a system of several rolls and furnaces, and a dense material can be obtained in this way. This method is probably applicable to several other metals and may play an important role in the future development of powder metallurgy. Another notable piece of European work (described in the short abstract below) points the way toward the commercial production of parts from aluminum powder — a most difficult operation.

Fig. 1 — Metallwerk Plansee at Reutte, Tyrol, Austria

Indicative of the progressive attitude of the industry, internationally, a seminar somewhat boldly called "De Re Metallica" was held in Reutte, Tyrol. The host was Metallwerk Plansee, the oldest, largest, and most progressive unit of the European plants.

Like some of the meetings in previous years, the program was not organized by one of the technical or scientific societies but by a group of interested companies. This particular seminar was organized by Paul Schwarzkopf, the well-known American pioneer in the field of powder metallurgy, head of American Electro Metal Corp. of Yonkers, N. Y., and sponsored by Walter J. Donnelly, U. S. High Commissioner for Austria. Figure 1 shows this plant and the mountains of the Austrian Alps surrounding this beautiful place. Approximately 300 scientists and engineers interested in the field of powder metallurgy accepted Dr. Schwarzkopf's invitation to the seminar, including 15 from the U.S.A., representatives of the Navy and other government agencies as well as men from universities and industries. It was an international meeting under the flags of 14 free nations.

Twenty-six technical and scientific papers were presented during the six-day meeting. They were arranged in three groups: *(a)* Hard Metals, *(b)* General Powder Metallurgy and *(c)* Physical Metallurgy.

HARD METALS

An important group of papers related to the hard metals, so called. They are placed first in this review because of the present importance of this branch of powder metallurgy. The expression "hard metals" — something of a misnomer — brings to mind first, of course, the sintered carbides so successful for cutting tools, drawing dies, and other uses requiring superlative wear resistance. They have been important commercial articles for so long that a considerable manufacturing art has been acquired, which is now serving the industry in the production of parts made of other sintered mixtures based on refractory oxides, borides and silicides, as well as carbides. These parts are of the greatest importance to gas turbines, which gain efficiency rapidly when operating temperatures at the blades are increased beyond the capability of the most heat resistant metallic alloys known.

C. Ballhausen (Krefeld, Germany) described the **Properties of Hard Metal Alloys.** For comparative presentation he plotted the properties of the hard metal alloys containing tungsten carbide and titanium carbide as space coordinates on a rectangular base having the volume ratio WC : TiC as abscissa and the cobalt content in area per cent as ordinate. This manner of plotting data on compressive strength, modulus of elasticity, hardness, modulus of rupture and cutting characteristics is a first step toward the standardization of hard metal alloys.

E. Fitzer (Technical University, Vienna, Austria) described his work on the development of **High-Temperature Materials by Silicizing Tungsten and Molybdenum.** The high-melting metals tungsten and molybdenum, which are strong at high temperatures, can be protected against oxidation by alloying with silicon; tungsten can be protected up to 2000° C. (3650° F.) and molybdenum up to 1800° C.

(3275° F.). The silicides of these metals have practical importance either in the form of thin surface coatings or bulk materials produced by powder metallurgy techniques. Alloy formation can be restricted to the surface by catalytic reduction of silicon tetrachloride with hydrogen. (This heterogeneous reaction can also be utilized for the manufacture of $MoSi_2$ powders.) The alloying of the pure components molybdenum and silicon in the solid state proceeds too slowly for the commercial production of surface layers on pieces of ponderable mass, but can be utilized for the preparation of sintered alloys from fine powders. The alloys of this group appear promising not only as heating elements but also for gas turbine and rocket applications. A complete outline of the process was recently published by the author in *Berg- und Hüttenmännische Monatshefte*, Vol. 97, 1952, p. 81.

During the discussion of this paper, one of the hosts, Dr. Kieffer of Metallwerk Plansee, exhibited several heating elements made from silicized molybdenum according to Dr. Fitzer's proposals. They were then heated to 1700° C. (3100° F.) in air without any oxidation observable after the experiment. He pointed out that the life of these new silicized molybdenum heating elements would be about equal to the heating elements now on the market. If this should be true, they may affect greatly the future development of electric furnaces. Dr. Kieffer also showed some of the new molybdenum disilicide heating elements made by powder metallurgy which withstood the same high temperature and which proved to have great mechanical strength. This manufacture of heating elements is definitely a new step in the development of powder metallurgy technique.

Preparation of Purest Titanium Carbide was described by G. F. Huettig (Technical University, Graz, Austria). In preparing all pure metal carbides, the following requirements should generally be met:

1. The chemical composition should correspond to the chemical formula.
2. The content of free carbon should be as low as possible.
3. The particle size distribution should be within certain limits.

To develop his ideas in a logical way the speaker summarized briefly the modern principles of inorganic chemistry, which are mainly based on the activated-state concept. The gas atmosphere in which the carbide is formed may be chosen for a purely catalytic effect, may act as pacemaker for the main reaction, or may participate in the reaction. If the last, a direct carburization by the gaseous agent must be distinguished from an indirect effect, which can be described as the creation of equilibrium conditions that prohibit the existence of free graphite.

Another series of principles discussed in his paper was based on the use of chemically active and therefore reactive starting materials, or the use of starting materials which during the course of the reaction produce in nascent state the components required to form the carbide.*

R. Kieffer (Metallwerk Plansee, Reutte, Austria) described the **Formation of Solid Solutions of Hard Metals.** By the term "hard metals" the author refers to the carbides, nitrides, borides and silicides of the transition metals of the fourth to sixth groups of the periodic table. The borides and silicides have recently found application in materials for high temperature. The main constituents of modern tool materials are the carbides of the transition metals — particularly binary and ternary solid solutions of these carbides.

The complete solid solubility of the isomorphous carbides of the metals of the fourth and fifth groups, as well as the partial solubility between these carbides and those of the sixth-group metals, was discussed. The cubic nitrides of the transition metals of the fourth and fifth groups form, with few exceptions, solid solutions with each other and with the isomorphous carbides of the same groups. While the carbides and nitrides usually have simple structures, the borides and silicides form a large number of hard metal phases with comparatively complicated structures. Isomorphous borides as well as silicides tend toward the formation of solid solutions, and Dr. Kieffer's presentation enables the student to follow, metallographically as well as by microhardness measurements, the diffusion processes involved.

A summary of the work which Prof. R. Kiessling of the University of Upsala, Sweden, did on ternary systems containing two transition metals and boron was presented in **Investigations on Ternary Systems Me_1-Me_2-B**

*The experimental material, part of which has not been published previously, was obtained at the Institute for Inorganic and Physical Chemistry of the Technical University of Graz, mainly by D. Schuler, V. Fattinger and K. Kohla.

and a Discussion of the Relative Strength of the Bond Transition Metal, Boron. For the systems Mn-Fe-B, Mn-Co-B, Mn-Ni-B, and Fe-Co-B the range between 33 and 50 atomic per cent boron has been studied. An equilibrium between two phases $(Me_1Me_2)_2B$ and $(Me_1Me_2)B$ exists and the directions of the tie-lines show that the metal with the lowest atomic number always is concentrated in the phase richest in boron. The data prove that the strength of the metal-boron bond within a certain transition series decreases with increasing atomic number of the metal.

John T. Norton (Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.) described his work on the **Ternary System Tungsten-Carbon-Cobalt.** Although alloys of tungsten monocarbide and cobalt have been extensively studied and widely used in the manufacture of tool materials, there is still considerable uncertainty about the nature of the true ternary phase diagram. Experimental investigations have established the ternary isothermal section at 1400° C. (2550° F.) and have shown, in addition to the well-known eta phase, two new ternary phases corresponding approximately to the formulas $Co_3W_6C_2$ and $Co_3W_{10}C_4$. The former has a cubic lattice and the latter is of hexagonal structure. Isomorphous phases were observed in the analogous systems containing iron or nickel. The reactions leading to the formation of these phases have been determined and a tentative phase diagram proposed. Evidence for the existence of stable and unstable equilibria was presented. On the basis of the proposed diagram, the reactions during the sintering of alloys of tungsten carbide and cobalt were examined and some of the details of the structure and physical and mechanical properties of cemented carbide compositions were discussed.

GENERAL POWDER METALLURGY

Leading off in a seminar on the unsolved problems confronting the powder metallurgy industry, busily engaged in the manufacture of bearings, porous diaphragms, small machine parts of intricate shape and good precision, G. J. Comstock (Stevens Institute of Technology, Hoboken, N. J., U.S.A.) and F. H. Clark (President's Materials Policy Commission, Washington, D. C., U.S.A.) discussed the **Development of High-Strength Heat Treatable Products From Alloy Powders.** In the opinion of these authors, the progress in the United States toward the development, production and application of fully alloyed metal powders is one of the most significant factors in widening the field of powder metallurgy. The types of materials now being produced, their general characteristics, the present preferred methods of fabricating pre-alloyed powders, and the potentialities presented by the development of high-strength, high-density, heat treatable materials were described at considerable length.

Many of the properties of fine metallic powders are so different from those, for example, of sand on the one hand and a more or less viscous fluid on the other, that investigators are presented with an almost unlimited field of study. In this general direction, E. Cremer (University of Innsbruck, Austria) described her **Determination of the *Haftkraft* (Adhesive Force) of Metal Powders.** The measurement of the glide angle of a powder dusted on a solid support determines a characteristic value which she terms "adhesive force" or "*Haftkraft*". This value depends on the surface properties of both powder and support, and is inversely proportional to the particle diameter of the powder.

A. von Zeerleder (Neuhausen, Switzerland) discussed his pioneering work in **New Developments in the Powder Metallurgy of Aluminum.** The rate of sintering of aluminum is slow and this metal therefore represents a special case in the field of powder metallurgy. Aluminum has so far been rarely used in the form of sintered products. The apparent density of commercial aluminum powder ranges between 0.1 and 0.3 g. per cc. so that an excessively large decrease in volume must occur during processing to a coherent mass. The powder Professor Zeerleder used for the manufacture of his sintered aluminum parts is trade named "S.A.P." (Sintered Aluminum Powder). It is prepared by an undivulged process so that it has, in spite of very fine particle size, an apparent density between 0.8 and 1.09 g. per cc. This powder is first prepressed cold at a pressure between 14 and 35 tons per sq.in. After being sintered at 500 to 600° C. (930 to 1110° F.), the compact was then hot pressed at 35 tons per sq.in. Thus, prepared cylinders were extruded at 500 to 600° C. at a pressure of 35 to 70 tons per sq.in. The extruded material can then be either die-forged or hot swaged. For some products, the cylinders may also be directly die-forged

instead of being extruded. The most outstanding property of the aluminum alloy products fabricated by this somewhat complicated procedure is the very high strength, particularly hot strength. This strength is dependent on final grain size in the product, and reaches, for powders in a particular size smaller than one micron, values exceeding 50,000 psi. Since each individual particle is coated by an oxide film, no grain growth is observed, even after long heat treatments. The creep strength and fatigue strength of S.A.P. products at 400° C. (750° F.) is also superior to that of conventional aluminum alloys. However, in the manufacture of compacts, the oxide must be closely controlled; higher oxide content increases the strength but, at the same time, reduces the elongation and toughness.

It would appear that the characteristics outlined indicate its suitability for engineering applications in the temperature range between 200 and 400° C. (400 and 750° F.).

H. H. Hausner (Sylvania Electric Products Inc., Bayside, N. Y., U.S.A.) discussed the **Effect of Lattice Changes on the Sintering Process.** Since the rate of sintering depends, among other factors, on the mobility of the atoms within the lattice, reactions which create lattice imperfections, lattice disturbances, or complete lattice changes may affect the rate of sintering. The author discussed his investigations on several reactions such as hydrogen reduction of an oxide and the decomposition of a hydride. The experimental results showed that lattice changes as obtained in these reactions affect the sintering process considerably. It is his belief that further studies in this field will result in an improvement of the sintering process.

Some Observations on the Mechanism of Liquid Phase Sintering were made by F. V. Lenel (Rensselaer Polytechnic Institute, Troy, N. Y., U.S.A.). He has been directing work of a group of experimenters on the iron-copper, copper-bismuth, copper-lead, and tungsten-copper combinations. They have determined the rate of densification and the microstructures of the sintered compacts. Liquid-phase sintering offers many advantages; it speeds up the sintering process considerably and usually results in a perfectly dense material. Some hypotheses concerning the mechanism of liquid-phase sintering were also presented.

E. M. Onitsch-Modl (Technical University, Leoben, Austria) spoke of the **Microhardness Test as an Auxiliary in Examining Sinter Changes in Complex Systems.** It is a simple and easily mastered method to examine alloying processes which are associated with changes in hardness, such as the Fe-C alloys containing the carbide-forming elements Cr, W, Mo and V. Diffusion processes which occur, dependent on the sintering temperature, both in the basic material and during formation of carbide, could be registered easily by microhardness tests. On some samples the speaker used the Reichert microhardness tester.

Some Contributions to the Physical Analysis of the Sintering Process were presented by G. Ritzau (Krefeld, Germany). Methods which elucidate the sintering mechanism by the direct measurement of changes taking place deserve special attention. Electrical conductivity and the thermo-electric potential appear particularly suited for a "physical analysis" of this type. Whereas the variation of the electrical conductivity is determined by both the change in porosity and the changes of the crystal structure which may be effected by diffusion, the variation of the thermo-electric potential is independent of porosity. Simultaneous measurements of the two electrical parameters therefore permit the investigator to determine the coincidental changes in porosity and atomic arrangement. The principles of the method were discussed for binary systems which exhibit either complete mutual solubility (copper-nickel) or complete mutual insolubility (copper-iron) in the solid as well as in the liquid states. For example, the poor sintering performance of nickel is clearly indicated. For sintered hard metals and sintered magnets, it was shown that the method of measuring thermo-electric potentials is capable of recording the course of sintering even in complex alloys.

In the group on "Physical Metallurgy", new experimental results were incorporated in a paper by W. Seith (University of Münster, Germany). Describing **New Concepts of Diffusion in Metals,** he explained how lattice imperfections are formed during the diffusion process; many lattices are never finally completed and a certain porosity and hole formation are observed. Seith demonstrated the hole formation by several photomicrographs of diffusion couples. The holes were observed especially in the regions of certain specific concentrations.

Short Runs

Plating

Hard and tough coatings of tungsten carbide can be plated by a process that does not heat the base metal above 400° F., thereby practically eliminating any danger of warpage or of altering the structure and properties of the metal part. The powdered tungsten carbide used in this process — called "Flame Plating" by its originators, Linde Air Products Co., New York City — contains 8% Co, and can be deposited in thicknesses of 0.0005 to 0.020 in. on nearly all metals and alloys. (As yet, a good bond cannot be formed between this coating and chromium plate, sintered tungsten carbide, nor on a flame-plated ground coating.)

Certain limitations exist as to the area that can be covered with the present equipment. The maximum size for flat surfaces to be used in the as-coated condition is 6 x 40 in.; for parts to be finish ground, maximum width is 3/4 in.; cylindrical objects can be 1/8 to 6 in. diameter and 40 in. long. Plating on irregular shaped parts is limited to an area contained within the two 45° angles from the horizontal plane, and on inside cylinder walls to a depth equal to the diameter.

Although the coating is hard (Rockwell A-89) it has a modulus of elasticity of only 15 million psi. as compared to about 90 million psi. for sintered carbide. This is an advantage because even a relatively light load will cause the coating to deform or yield slightly and thus it is distributed over a larger amount of the bearing surface; at the same time, this yielding more nearly conforms to the deformation in the base material under load than does a less elastic coating which has a greater tendency toward cracking under similar load conditions.

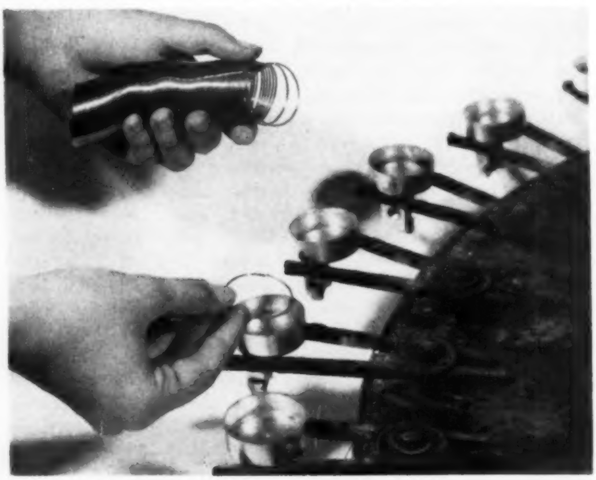
The plating has been tested in service on a variety of items so as to obtain its performance under conditions of shock, friction and abrasion. For example, plug gages coated by this method showed a service life of 5 to 1 over a gage made of boron carbide and 3 to 1 over sintered tungsten carbide; a burnisher produced 10 times as many parts as the chromium-plated kind; a paper-slitter knife with this coating outlasted the steel knife previously used for the same cardstock by two life cycles; a circular saw in a lumber mill has given double the usual service.

Brazing

A problem arising in production was solved by Lucas-Milhaupt Engineering Co., Cudahy, Wis., and might offer similar benefits to others using preformed rings. The difficulty was in handling the rings of brazing metal as they were inserted into the assembly (connectors for electrical transformers). The looseness and tangling of these rings slowed the operation.

Preforms were made by winding wire, of the same kind used for the rings, into coils and then slotting the coil along the outer diameter about half through the wire so each ring could easily be broken off the coil, one at a time (Fig. 1). Output of the

Fig. 1 — Faster Handling Is Obtained With These Preforms



brazed units was increased about 60% as a result of this simple idea. Another cost-cutting technique devised by the company is to form washers for brazing and soldering by flattening rings of round wire. This reduces the cost of such preforms because there is no scrap and less expensive dies can be used than with the stamping process. Both the notched-coil rings and the washers are made to customer's specifications.

Testing

GENERALLY SPEAKING, the easier a steel sheet can be bent, the better are its drawing properties; stamping press operators, die setters and inspectors have used rule-of-thumb in a rough way by bending the corners of the sheets with their hands. Charles B. Buker, a metallurgist at Jones & Laughlin Steel Corp., has adapted this idea to a test which measures the ductility of the sheet in relation to a standard bend. A simple instrument was evolved by Buker and his associate, J. R. Speer.

The test is made by engaging a corner of the sheet, applying downward pressure on the handle so that the base of the instrument rolls into the position shown in Fig. 2; simultaneously the gage is read. If the gage indicates that the resistance to the flexing force is less than 60 units, the steel can be drawn satisfactorily; above 60 units the steel will probably break during a heavy draw.

After the flexure test is made, a spherometer is used to measure the diameter of the bend (Fig. 3), and this will indicate whether the stamping will develop stretcher-strains. As the diameter read on the spherometer falls below approximately 3 in., the point where there is no tendency for stretcher-strains, the degree of liability toward stretcher-strains is inversely proportional to the decrease of the bend diameter. Both of these instruments will be made by Steel City Testing Machines, Inc., Detroit.

Fastening

BECAUSE MAGNESIUM ALLOYS have low resistance to abrasion, special consideration must be given to this factor in the design of products calling for tapped holes. This problem came up when the side covers of a calculating machine were changed from aluminum to magnesium alloy to reduce their weight. Required strength at threads for cap screws was obtained by inserting helical coils of diamond-shaped wire.

The coil inserts, made by Heli-Coil Corp., Danbury, Conn., have an outside diameter slightly larger than when installed; this forces a fit between insert and the tapped thread in the magnesium that is sufficiently tight to prevent the insert from backing up should the fastener be unscrewed. Strength of threads formed by the wire (of stainless steel to avoid a galvanic couple with the magnesium) is about 50% greater than of those formed in magnesium.

Fig. 2 — (Left) Flexure Test for Drawing Properties. Fig. 3 — (Right) Spherometer Shows Tendency for Stretcher-Strains

An Eminent Living Metallurgist

L. A. Danse
Supervisor of Materials and Processes
Production Engineering Section
General Motors Corp.

A Biographical Appreciation

In retrospect, it is often the trivial things which loom large in shaping the destiny of men. For L. A. Danse, now supervisor of materials and processes in the Production Engineering Section of General Motors Corp., Detroit, a pretty young Indiana girl nipped a youthful allegiance to the West, and the fatherly tutelage of "Uncle John" Keller at Purdue University steered to the automotive industry one of its most renowned metallurgists and brilliant engineering minds. At the same time they brought to the ⊕ in its prenatal days an energetic organizer and tireless leader. Otherwise, "L. A." (that's all anybody in the industrial world has ever been known to call him) might still be a jackleg miner, roaming the Rockies from Canada to Mexico in search of rich ore strikes.

He was born in Helena, Mont., and in his youth followed his miner father all over the awakening West, with one fairly extended period in Deming, N. M., where he boned up on mining engineering. During these impressionable years he grew to know and love nature — the forests, the birds, the fish, the wild life — an affection which continues to this day and has had much to do with his consuming interest in conservation and the control of air and water pollution.

Skipping now to the time when he journeyed to Indiana and became "civilized", the young Danse spent two years studying metallurgy at Purdue. He left in 1913 to become general foreman in the assembly and test department of Atlas Engine Works in Indianapolis. Here he gained his first intimate knowledge of gasoline engines which was to stand him in good stead in his later years with the mushrooming automotive industry.

"I owe a tremendous debt to Uncle John Keller at Purdue for having set me straight in my early metallurgical career," L. A. recalls; "he seemed almost more a father to me than to his own offspring."

It was probably Keller who urged him to take the job as superintendent of heat treat at Dayton Engineering Laboratories Co. (forerunner of GM Research and Delco, and the site of Boss Kettering's early "tinkering"), but he soon returned to Indianapolis (the pretty girl?) to become metallurgist for Diamond Chain Co. There, in addition to supervising control of raw materials, heat treatment and testing of finished parts, he developed a novel continuous cyaniding furnace, about 14 ft. long, in which the parts to be hardened were carried through the hot bath on a conveyer chain.

In 1916 L. A. joined the Steel Treating Research Club of Detroit, one of the two nuclei of the American Society for Steel Treating, now ⊕. There were only a couple dozen members then who would get together regularly to discuss heat treating problems. A similar group in Chicago was known as the Steel Treaters' Research Society, and it took the organizing ability, persuasiveness and spark-plugging of W. H. "Bill" Eisenman, plus a lot of spade work by men like Professor Keller and A. E. White of the University of Michigan, to effect the eventual amalgamation in 1920. Danse was chairman of the Detroit Chapter in 1920-21 and national vice-president the following year.

Many others gave tirelessly o[f] their time and effort in these embryonic d[a]ys of the A. S. S. T. — C. N. Dawe, Lloyd and W. P. "Billy" Woodside, Lans McCloud, Carl Ethier, Ed Stilwill, to name only a few, all of them destined to become metallurgical leaders in the rapidly expanding automotive industry.

From the windows of his spacious office on the 15th floor of the General Motors Building, L. A. occasionally finds time to look out across the south and west sides of the Motor City, doubtless calling to mind the time he first arrived on Jan. 12, 1918, in a blinding snowstorm. He was to supervise tool and production heat treatments at Henry M. Leland's Lincoln Motor Co. He lost no time in bringing in new ideas. His continuous cyaniding setup was modified into a four-pot unit, with low-grade cyanide in the first or preheat pot. A sharp increase in pot life was realized. Another innovation was carburizing camshafts in steel tubes packed with compound. They could be rolled easily through the carburizing furnace, vastly faster than with former box methods.

In May 1919, Danse transferred to Cadillac as chief metallurgist. There was a big job to be done. The war was over and the grueling times of building Liberty engines on a cooperative basis were past for the auto builders. A new Cadillac plant was being outfitted. Available heat treating furnaces were old and obsolete. Welding was coming in. Danse had his work cut out for him.

Realizing he had "found himself" and that the automobile was his baby, he rolled

An Eminent Metallurgist

up his sleeves and waded into the new job with enthusiasm that has never diminished. He drew up the original S.A.E. specifications for automotive cast iron that were to stand virtually unchanged for 14 years. He sparked the further mechanization of heat treating operations, always stressing quality of product and precise control.

While at Cadillac, L. A. became a flying enthusiast, and over a period of seven years starting in 1927 spent much of his spare time buzzing around the upper air in his Challenger with Curtiss OX-5 engine, and later a De Haviland Gypsy Moth. By his side usually rested his trusty Leica camera which he still carries in his briefcase when making trips to General Motors plants throughout the country. He is an inveterate lens hound and claims still to have in his files photographic plates which he took of the naval parade up the Hudson River following the Spanish-American War.

Over the years his professional interests broadened beyond the confines of strictly metallurgical work, encompassing chemistry, forging, foundry, lubrication, painting, packaging, plating and industrial waste control. After almost 25 years as chief metallurgist, L. A. relinquished these duties to become a technical adviser, or trouble shooter as he calls it, on all these manufacturing phases. This led to his next step up the ladder, when in 1944 he became assistant to Director Rolly Wilhite of the GM Production Engineering Section.

In this work he is what might be called a clearinghouse for gathering, screening and disseminating technical information on materials, processes, equipment and operations used throughout the 112 GM manufacturing plants. He is on the go almost continuously, attending meetings of committees, working groups, supervisory conferences and the like, all aimed at bettering manufacturing efficiency. Much of this activity leads to the development of standards. The GM standards book, continually in process of revision and extension, has no counterpart anywhere in the world. It is the bible of suppliers, the envy of competitors.

L. A. is particularly proud of his work in the field of industrial waste control and his efforts to minimize pollution of air and water. GM alone has spent $16 million in control of water pollution, and $27 million in control of air contamination. Several years ago Danse was appointed by the President to represent industry on the Federal Water Pollution Control Advisory Board, where he sponsored a national technical task committee of the Public Health Service. This committee represents 35 industries, attacking the problem of waste control.

His childhood love of the outdoors finds expression in Boy Scout activities. A 30-year veteran, he holds the Silver Beaver award and is a former scoutmaster and district commissioner. He has long held memberships in the Izaak Walton League, Audubon Society, American Forestry Association, National Geographic Society and American Nature Association.

This part of his life perhaps explains his deep religious convictions. He can and will deliver a bang-up sermon at the lull of a conversation. The story is told of a Sunday morning committee meeting which he directed in Washington during the war. L. A. apologized for having kept many of the members away from church and proceeded to atone for the breach by reading from the Scriptures for ten minutes.

His memberships in engineering and technical societies begin with the embryonic in 1916 and now include a total of 19 — local, state, national and foreign. As might be expected, much of his time is spent in activities of the S.A.E. He is a member of the executive committee of the Iron and Steel Technical Committee and chairman of the Miscellaneous Users Panel of that committee, sponsor of a sectional committee on classification of materials for tools, fixtures and gages, and serves as S.A.E. representative to the Advisory Council of the Federal Specifications Board.

It is a fair question to ask whether L. A. ever finds time to go home. The answer is an emphatic yes. There are few more devoted husbands and fathers. He will frequently bring Mrs. L. A. with him to meetings at which he is the featured speaker — always talking extemporaneously.

Danse is at his best when extemporizing. Thought keeps tumbling over thought and the words pour forth loudly, clearly and convincingly. He would have made a great evangelist. Perhaps he is an industrial evangelist — exhorting and cajoling his listeners to stir them toward higher efficiency and a more humanized approach to their jobs.

Arthur H. Allen

Production of Uranium in the U. S.*

URANIUM ore output within the United States remains a fraction of total output from the free world, and likewise a fraction of our total national demands. This is true even though domestic production has risen sharply over the past two or three years.

The Atomic Energy Commission's domestic ore program first got under way in late 1948 on an exceedingly modest scale. It concentrated mainly upon the Colorado Plateau area, which is today the only significant domestic source of supply.

In this area the Commission owns and operates an ore-processing mill at Monticello, Utah, and several ore-buying stations. A mill is under construction at Grants, N. M. Five privately owned mills are located in Colorado and two in Utah.

Production to date has come largely from the old vanadium mining areas of western Colorado and eastern Utah. To the south and west of this region, along the Colorado River, lies an area as large as New England and embracing some of the roughest country in the United States. Here is a great desert and mountain region essentially without roads or water, but containing many miles of outcrop.

During the past 18 months, the Commission has undertaken a considerably increased exploration effort on the Colorado Plateau, consisting of geological studies and a diamond-drilling program designed to locate ore.

In the early postwar years, the belief came to prevail that the availability of uranium ores imposed a narrow and rigid limit upon atomic production, even though only 7% of the A. E. C. expenditures were devoted to all phases [of exploration, procurement, processing of ores, and preparation of feed materials to reactors and diffusion plants].

Although there was little validity to the official doctrine that uranium ore supplies were rigidly limited, this doctrine did in fact play a key role in early decisions as to scope and scale of our national atomic production effort.

This subcommittee has been informed that sound processes are in hand for practical and speedy recovery of this uranium as a byproduct of the Florida phosphate fertilizer industry.

The quantity of uranium ore obtainable [from American sources] rises or falls with the degree of effort exerted to this end. Just as any raw material may be produced in greater quantities, given time and given a willingness to pay the necessary cost, so uranium may also be procured in greater quantities.

However, the United States has such great need for uranium and thorium that procurement from foreign sources should also be rapidly and substantially increased. Effort along these lines should reflect a sense of urgency created by full awareness of the possibility that at some future date certain foreign sources might be cut off.

A principal point which the subcommittee wishes to make as regards the availability of uranium ore is this: Within wide limits which have yet to be approached, the military are free to recommend allocating as large a share of the total national defense budgets to the quantity production of atomic weapons as they deem advisable. In other words, so far as uranium raw materials are concerned, the military may ask for and get — following several years of "lead time" — as many bombs as they consider to be necessary to deter war or to win a war quickly if it comes.

†Receipts of uranium concentrates were according to schedule.

Several of the existing ore processing plants on the Colorado Plateau enlarged their facilities and further expansion is planned. Construction of 783 miles of access roads costing nearly $4,200,000 has been started and additional projects are planned. Over $600,000 has been paid as bonuses for initial production to more than 450 uranium mining properties.

Initial production of uranium from phosphoric acid is expected this year.

In Canada, additional mill facilities are now in operation at Eldorado mine on Great Bear Lake. The first of several plants being constructed in South Africa to recover uranium from the gold ores of the Rand is nearly ready to start production. An agreement was reached with Australia to supply uranium to the United States.

An extensive exploration program continues in the Colorado Plateau area — the most favorable geologically in the U. S.

Scintillation-type detectors have been developed for use in airborne radioactivity surveying. About 22,500 miles of reconnaissance flying was done on the Colorado Plateau; 50,000 miles of flying is planned for 1953. Results will be checked by field parties.

More than 1,000,000 ft. of exploratory drilling was accomplished during the year and 1,500,000 ft. is planned for fiscal 1953. An improved drill-hole logging device provides more accurate data on the radioactivity exposed in these drill holes.

Loans totaling over $475,000 were approved in the past six months by the Defense Minerals Exploration Administration for exploration and development at 14 uranium mines in the West.

*Verbatim extracts from House of Representatives Report No. 2449 (July 2, 1952) on Raw Materials, by the Congressional Joint Committee on Atomic Energy.

†From here on, the information is taken from the 12th Semiannual Report of the Atomic Energy Commission, July 1952.

By Allen G. Gray, Consulting Editor to Metal Progress

THE APPLICATION of an aluminum coating to steel has long been of interest and numerous approaches have been followed. Investigations recently conducted with different plating baths at Battelle Memorial Institute and at the National Bureau of Standards show promise of opening the door for commercial applications of electrodepositing aluminum. Aluminum-coated steel has shown a high resistance to rusting in industrial and seacoast exposures.

Recent Developments in Protective Coatings

High-purity aluminum deposits, 0.65 mm. or more thick, were produced in Battelle work (reported in *Journal* of the Electrochemical Society, Vol. 99, 1952, p. 53, by W. H. Safranek, W. C. Schickner, and C. L. Faust) from a plating bath consisting of a dispersion of toluene in a toluene solution of the fusion product of ethyl pyridinium bromide and aluminum chloride. Methyl t-butyl ether, or another addition agent, was used for improving the physical properties of the deposit. The electrodeposition of aluminum was investigated with the objective of electroforming lightweight waveguides that could be tested for radar wave transmission characteristics. The aluminum deposits were dense, strong and ductile. Further investigation on electrodeposition of aluminum from this system as a protective coating was recommended. Figure 1 shows an aluminum waveguide deposited from this bath.

In preliminary tests, it was found that a bath described by Hurley and Wier (*Journal* of the Electrochemical Society, Vol. 98, 1951, p. 203) produced better aluminum plate than any of the others investigated. It was prepared by fusing one mole of ethyl pyridinium bromide with two moles of anhydrous aluminum chloride and adding benzene or toluene until a second layer formed on top of the plating solution. Aluminum was plated on cathodes in the lower layer. Attempts to electrodeposit aluminum thicker than 0.05 mm. (0.002 in.) resulted in "lacy" nodular metal with an unsuitable surface. The Battelle tests led to the selection of methyl t-butyl ether as the best addition agent effecting the necessary improvements in the aluminum plate. The preferred bath for aluminum plating is composed of 32% by weight of a fusion product of 1 mole of ethyl pyridinium bromide plus 2 moles of aluminum chloride, 67% toluene (sp. gr. 0.866), and 1% methyl t-butyl ether.

The temperature of the plating bath was maintained at 30° C. (86° F.). The direct-current density on the cathode was 10 to 20 amp. per sq.ft. A superimposed alternating current of 1.5 to 2.5 volts was found to improve the physical characteristics of the deposit. The addition of methyl t-butyl ether to give a smooth plate did not affect the microstructure of the deposit. Atmospheric corrosion tests conducted by Hurley and Wier on steel that was plated with aluminum in this type of bath showed that the plate retained a shiny appearance and had only occasional pinholes. These pinholes did not spread and rusting under the aluminum did not take place.

Bureau of Standards' Bath — The new bath developed at the National Bureau of Standards (described by D. E. Couch and Abner Brenner at the 100th Meeting of the Electrochemical Society at Detroit) consists of an ethereal solution of anhydrous aluminum chloride and a metallic hydride. Optimum concentration of the aluminum chloride is in the range of 265 to 400 g. per l. The hydride is added as lithium hydride in concentrations of 4 to 8 g. per l., or as lithium-aluminum hydride. The bath is operated at room temperature and at current densities up to about 50 amp. per sq.ft. Anode and cathode efficiencies are about 100%.

The plating solution is stable over long periods of time if moisture is excluded. Baths which have absorbed moisture require the addition of lithium hydride to replace that decomposed by moisture. Sometimes the addition of aluminum chloride as well as lithium hydride is required for rejuvenation. With the optimum amount of lithium hydride (4 to 8 g. per l.), the aluminum deposit was matte and very white. The smoothest deposits were made using periodic reverse current which involves making the article to be plated alternately anodic and cathodic ac-

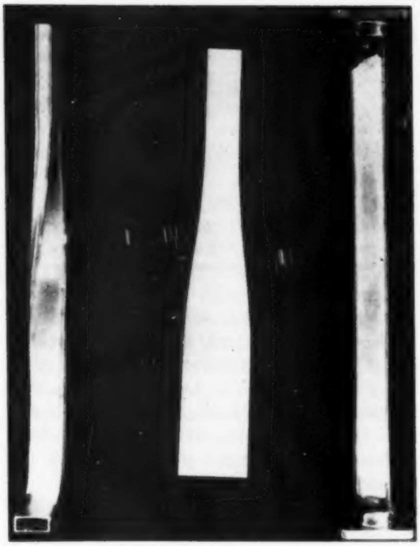


Fig. 1 — Experimental Aluminum Waveguide Segments Electroformed at Battelle Memorial Institute. (Courtesy Electrochemical Society)

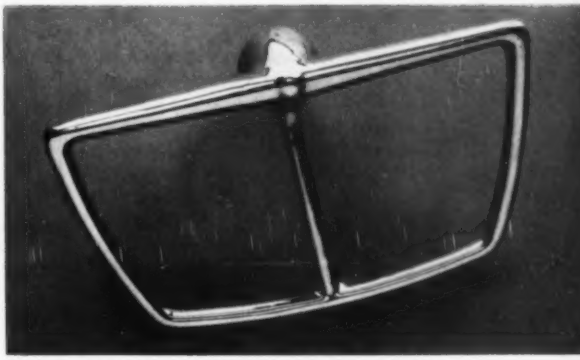


Fig. 2 — Cast Magnesium Aircraft Control Wheel With a Bright Copper-Nickel-Chromium Plate. (Courtesy Dow Chemical Co.)

cording to a predetermined cycle. Smooth, sound deposits 0.75 mm. thick were produced, but they were harder and less ductile than deposits made with direct current.

PLATING ON MAGNESIUM AND ALUMINUM

Magnesium and aluminum as base metals require special pretreatments to secure adhesion of the plated coating, and in recent years, advances have been made in developing practical plating methods. Work conducted by Dow Chemical Co. resulted in a method for plating on magnesium that is based on a zinc-immersion pretreatment. In general, the process consists of an initial application of zinc coating by immersion followed by copper striking and electroplating in standard plating baths. The success of the process is dependent almost entirely upon the adherence of the zinc coating. This method opens up a field for the use of magnesium for many applications requiring a bright finish, resistant to tarnish, corrosion or wear. Figure 2 shows an aircraft control wheel made from a magnesium casting that has been finished in a bright chromium plate.

The composition of the zinc immersion solution recommended by Dow Chemical Co. is shown in Table I. The immersion dip is operated at a temperature of 80 to 85° C. (175 to 185° F.). Parts are immersed for 3 to 5 min., then rinsed in cold water and transferred immediately to a copper strike bath especially designed for plating over the zinc immersion coating. A suitable copper strike bath can be prepared using the following composition:

Copper cyanide	3.5 oz. per gal.
Potassium cyanide	6.1
Potassium hydroxide	1.0
Potassium fluoride	4.0
Potassium carbonate	2.0

The free cyanide should be maintained at about 1.0 oz. per gal. and the bath operated in the pH range 12.8 to 13.2 at a temperature of 54 to 66° C. (130 to 150° F.). Parts may be transferred to a regular alkaline copper bath after striking. Other metals may be plated on the copper deposit. Prior to the zinc immersion pretreatment, magnesium parts must be suitably cleaned and pickled. A 90% (by volume) solution of 85% phosphoric acid used at room temperature for an immersion period of 1 min. has been used to pickle die castings of magnesium alloys.

Plating on Aluminum — A practical method for plating on aluminum alloys, de-

Table I — Zinc-Immersion Solution for Magnesium

Constituent	Grams per Liter	Ounces per Gallon
Sodium pyrophosphate ($Na_4P_2O_7$)	120	16
Zinc sulphate ($ZnSO_4 \cdot 7H_2O$)	40	5.2
Potassium fluoride (KF)	10	1.3
Potassium carbonate (K_2CO_3)	5	0.67

veloped by the Aluminum Co. of America, utilizes a zincate immersion pretreatment prior to plating in a copper strike bath. A typical immersion bath for zinc coating has a composition of 525 g. per l. (70 oz. per gal.) of commercial 76% caustic soda and 100 g. per l. (13.3 oz. per gal.) of zinc oxide. Aluminum parts to be plated are immersed for a period of ½ to 2 min. at room temperature. (Figure 3 gives the weight of zinc deposit obtained with different immersion periods on various wrought aluminum alloys.) The parts are rinsed and plated in a Rochelle-type copper strike bath at room temperature and then they can be transferred to the regular plating baths. Aluminum parts should be suitably cleaned and pickled prior to the immersion treatment.

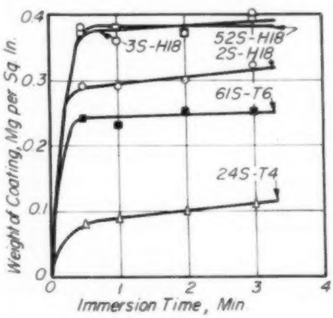
TIN-ZINC ALLOY PLATING

Investigations conducted in the laboratories of Metal and Thermit Corp. have resulted in a potassium-type, tin-zinc alloy plating bath. It is reported that this process has found acceptance in many fields, but greatest interest has been shown in the electrical and electronic industries, where the combination of corrosion resistance and good soldering characteristics has been particularly attractive. The 80% tin, 20% zinc deposit is said to be among the best corrosion resistant electroplates ever developed. Typical applications are: radio and television chassis and miscellaneous radio parts; hardware, including automotive, industrial, and general; fire extinguishers; and die castings. The process is adaptable to most types of plating equipment, including still tanks, automatics, and barrels. Formulations of the all-potassium bath suggested for still tanks and automatics, and for barrel plating are given in Table II. Recommended temperature of operation of these baths is 150° F. Cathode current densities are within the range of 10 to 75 amp. per sq.ft. for still plating. For still tanks, a 6-volt d.c. source is usually sufficient.

Table II — Potassium Bath for Tin-Zinc Alloy Plating

Constituent	Make-Up in Oz. per Gal.	
	Still and Automatics	Barrel
Potassium stannate	16.0	12.7
(Tin equivalent)	6.0	4.7
Zinc cyanide	1.2	1.8
(Zinc equivalent)	0.67	1.0
Potassium cyanide	2.8	2.0
Free potassium hydroxide	0.87	1.3

Fig. 3 — Weight of Zinc Deposit on Various Wrought Aluminum Alloys With Different Immersion Periods. Zinc immersion is followed by copper strike and conventional plating. (Courtesy Aluminum Co. of America)



The Tin Research Institute reports that the cost and scarcity of cadmium has doubtless stimulated interest in tin-zinc alloy plating, but this is not the only reason for expansion of the alloy plating process. At the present stage of development, according to the report, a sodium-type tin-zinc plating bath is being used in Great Britain for finishing of motorcycle components, typewriter parts, tools, skates, carburetors, printers' equipment, and many other articles. A particularly interesting development is the plating of nuts and bolts and other components which are to be used in contact with aluminum, to avoid galvanic corrosion that so often occurs in assemblies where aluminum is in contact with another metal. In salt-spray tests it was found that the tin-zinc alloy coatings not only protected the steel bolts but gave rise to a minimum amount of corrosion of the aluminum plates, as illustrated in Fig. 4.

Improvement of the surface stability of molybdenum is one of the most important problems to be solved to promote its successful high-temperature use (above 1600° F.) in such applications as heat engines. Various methods of providing adequate surface protection are being investigated. Work conducted at Battelle Memorial Institute has shown that the siliconizing of molybdenum is a very effective way of imparting the corrosion resistance

of a silica glass to this highly refractory metal. Molybdenum may be siliconized by a variety of methods such as hot dipping, spraying and heating in a silicon pack. However, one of the most effective methods is by treatment in a hydrogen-silicon tetrachloride atmosphere at 1830 to 2900° F., employing vapor deposition.

The Fansteel Metallurgical Corp., who cooperated with Battelle in this development, has recently announced the availability of siliconized molybdenum bar, rod, wire, tubing, and fabricated parts. The siliconized coating is not only impervious to oxygen, but appears to be unattacked by nitrogen, carbon monoxide or the sulphurous or hydrocarbon atmospheres commonly resulting from combustion, and is resistant to thermal shock. Unlike ceramic coatings, the siliconized coating is a conductor, so that electrical contact can be made through the coating. Although the coating is extremely hard, pieces can be worked to a limited extent.

Protective Coating for Molybdenum

Fansteel reports that siliconized molybdenum is an excellent material for gas and oil burner nozzles and jets. Coated wire can also be used for spark gaps in burner ignition systems. Parts for jets include nozzles, flame holders, mixers, thermocouple wells, gas sample tubes, and probes. Other uses include gas-turbine combustion chambers and heating elements for electric furnaces.

Battelle tests showed that in siliconizing molybdenum, two types of coatings are generally obtained, depending primarily upon the coating temperature and to a lesser extent on the gas-flow rate and the concentration of silicon tetrachloride. Below 1420° C. (2590° F.), the melting point of silicon, the coating may be either two or three-phase, depending on whether or not an outer layer of silicon is obtained. In the three-phase coating, layers of Si, $MoSi_2$, and MoSi are present, while the two-phase coating consists of an outer layer

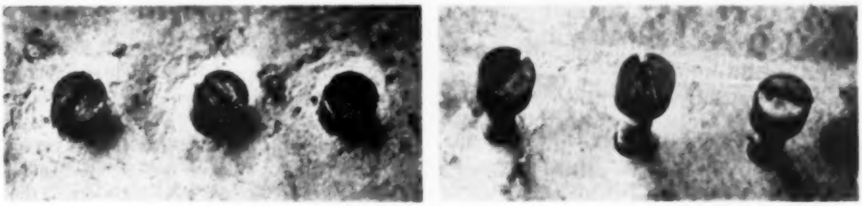


Fig. 4 — Results of Salt Spray Tests for 26 Weeks on Steel Screws Inserted Into Aluminum Plates. Bare steel screws at left; steel screws plated with tin-zinc alloy at right. (Courtesy Fulmer Research Institute)

A molybdenum strip that was protected against oxidation by the siliconized coating withstood months of heating in air to temperatures exceeding 2000° F. The life which may be expected in still air under conditions of no mechanical stress is indicated below:

Temperature	Expected Life
1500° F.	6000 hr.
2000	2000 to 2500
2500	200 to 800
3000	50 to 300

The bond between the coating and the base metal is integral. Commercial applications of siliconized molybdenum will probably be made in the temperature range between 2000 and 3000° F., beyond the range of nickel-chromium and similar alloys. The upper limit is imposed by the melting point of the molybdenum silicides.

of $MoSi_2$ and an intermediate layer of MoSi. Above the melting point of silicon, only the two-phase coating is normally obtained. However, if deposition is carried out at high gas-flow rates or with high concentrations of $SiCl_4$ in the plating atmosphere, a layer of molten silicon can be obtained. By using low flow rates or low concentrations of $SiCl_4$, the formation of free silicon coatings below 2550° F. can be avoided. A coating of free silicon can be converted into molybdenum silicide by holding the coated sample at a temperature just below the melting point of silicon. The concentration of $SiCl_4$ in the plating atmosphere and deposition temperature are not critical; almost identical performance was obtained with wires given coatings of equal thickness at temperatures from 2550 to 3090° F.

By J. D. Graves, Stanford Research Institute, Stanford, Calif.

Metals in Radioactive Static Eliminators

Radioactivity is of prime importance to the average citizen because of its value in medicine — the treatment of cancer and the exact location of circulatory stoppages. It is of fundamental importance to the physicist because it is so closely related to the structure of the atom. It is of growing importance to the metal engineer because, after all, the naturally radioactive materials are heavy metals, the radium substitutes are also metals, and an increasing amount of radioactive waste from the plutonium piles consists of rare metals whose utilization requires metallurgical skill of advanced degree.

Aside from the well-publicized use of radioactive materials in medicine, scientific research, and subsurface inspection, the rather new industrial application of "radioactive static eliminators" deserves description in *Metal Progress*. While most static eliminators are used in other industries, they have use and future possibilities in the metal industry; and, as already said, they depend upon *metal* — metal of curious properties.

Static formation may constitute a serious problem in many industrial processes. Moving nonconducting materials, such as paper, cellophane, dusts and rayon, create and store static electricity at points of friction — for example, where paper leaves a roll. This is the same static known to every school child who has seen a comb give off sparks or attract bits of paper on a dry day. Sparks from static charges may ignite inflammable dusts, metal powders, gases or vapors. Statically charged materials tend to stick together, to repel each other, or to attract foreign materials, and thus interfere with production.

Use of radioactive static eliminators is not a panacea for all such problems, but their advantages insure wider adoption as practical experience is acquired. The expected availability of large quantities of relatively low-cost radioactive materials would extend the range of application.

Radioactive static eliminators emit alpha, beta, or gamma rays, or a combination thereof. These radiations ionize the air or gas surrounding the radioactive source. Ionized gas is a conductor of static electricity and serves as the invisible mechanism which carries the trouble-making static electricity harmlessly away. Figure 1 shows how the eliminator functions, using paper coming from a belt or roll as an example. Friction at the point where the paper leaves the belt causes it to become electrically charged with respect to the belt. As a result, the belt and paper may attract each other and become difficult to separate. The effect of the radioactive static eliminator is to ionize the air where the paper and belt part. The positive air ions will flow to the paper and the negative air ions to the belt, neutralizing both and eliminating the attractive forces.

Alpha particles (doubly ionized helium atoms) are very heavy and will ionize air only a short distance away from the source. Therefore, alpha emitters must be placed within a few inches of the spot where the static electricity is to be bled off. Where it is desirable to eliminate static electricity over several small areas, such as in the paper-belt separation, alpha-emitting eliminators are effective. The advantage of alpha particles is their high ionizing ability, allowing use of small quantities of radioactive material.

Beta particles are 7000 times lighter than alpha particles and ionize air out to a few feet from the source of radiation. Each beta particle will produce the same total number of ions as each alpha particle of the same energy, but a beta source will distribute the ions through a much greater volume of gas than an alpha source. The number of ions per unit volume of air is correspondingly smaller with beta radiation. Consequently, much more radioactive material would be required to eliminate static from the paper-belt separation process with beta particles. From this standpoint of energy utilization, beta rays are efficient for static elimination only when relatively large surfaces must be discharged.

Gamma-ray eliminators are in the realm of possibility, with large sources of such rays

in prospect. Their utilization, however, would be limited to processes where it is necessary to ionize large volumes of air in an uninhabited or heavily shielded area. Gamma radiation could be utilized to advantage where the charge is drained through liquids or solids.

Fig. 2 — Commercial Static Eliminator Consists Only of a Bar of Metal Holding a Foil of Radioactive Material Such as Radium, Radium-D or Polonium. (Courtesy United States Radium Corp.)

METALS FOR STATIC ELIMINATORS

Figure 2 shows a commercial static eliminator consisting only of a bar of metal holding a foil of radioactive material. The ionizing radiation is directed toward the statically charged material and shielded in other directions. Radium, radium-D, or polonium may be the radioactive material. Radium emits alpha, beta, and gamma rays; radium-D emits alpha and beta rays; and polonium emits alpha particles only.

If the presence of beta and gamma radiation is permissible, radium has the advantage of a 1600-year half-life (the time it takes for the radiation to decrease to one-half its original intensity). Where gamma radiation is not permissible, radium-D may be used. It has a half-life of 22 years, but is not practical as a beta-emitting eliminator because of its cost. Where neither beta nor gamma radiation is permissible, polonium may be used. This has a half-life of only 138 days, requiring periodic replacement.

With the exception of cobalt, all of the radioactive materials for static eliminators, now and in the foreseeable future, are rare and have little use other than for their radioactivity. Radium is a naturally radioactive white metal that becomes black on exposure to air. It decomposes water and blackens organic matter on contact. Radium constantly gives off heat, its temperature being about a degree and a half higher than that of its surroundings. It decays to lead.

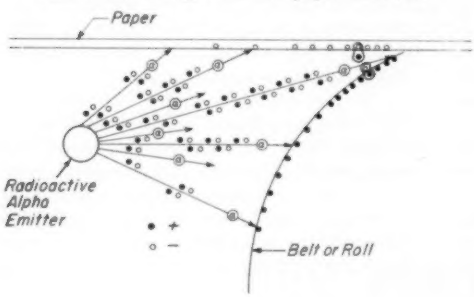
Polonium occurs in nature as a radioactive decay product of radium. It is very rare and has been isolated only in small quantities. Because it decays so rapidly, it always exists with lead, the final decay product.

Strontium is a brass-yellow metal with no industrial use in the metallic form. It is nonradioactive in the natural state, the radioactive form being a fission product which decays to zirconium.

Cesium is a silvery white metal resembling potassium. It is softer than beeswax and must be kept out of contact with air or water. The metal is used in photo-electric devices. It occurs in nature only in the nonradioactive form. The radioactive material is a fission product and decays to barium.

Health Hazards — Radioactive static eliminators are completely safe if properly constructed, installed, and used. On the other hand, they can be serious hazards if misapplied. The responsibility for construction and installation must fall to those fully cognizant of the properties and potential hazards of radioactive materials; they must recognize and provide safeguards for inexperienced operating personnel. Some commercial suppliers of radioactive static eliminators review the proposed use, supervise installation, and educate the consumer — a most desirable arrangement. The consumer should also have the eliminator and the surrounding equipment checked periodically by the supplier or a radia-

Fig. 1 — Schematic Diagram of Radioactive Static Elimination in a Paper Mill. Alpha particles, α, produce charged ions which are attracted to and neutralize the opposite static charges on the paper and roll



tion detection service to assure its safe continuance — at least until the particular device is proved safe in its environment.

A great deal of care must be exercised in construction of the equipment. The radioactive material should be completely enclosed so that no radiation becomes unshielded and no portions of the material can be scraped off or will scale off to disperse where it can be inhaled or ingested.

Pure alpha emitters will cause no damage outside of the body since they cannot penetrate the skin. If they are inhaled, ingested, or absorbed into the body, they will deposit and cause tissue destruction. It is very difficult to enclose alpha emitters and still permit the alpha radiation to escape and be used for static elimination. The alpha-emitting material is generally impregnated into some metal foil such as gold, and plated with another metal for complete enclosure. This plating must be very thin to allow passage of the alpha particles. It is therefore delicate and must be handled carefully. In use, it should be mounted so that no moving material can contact it and no one can touch the plated surface.

Beta emitters can be encased in a more substantial material, such as thin metal or plastic foil. Beta particles are more penetrating than alpha, and strong beta sources may cause physical damage to a person exposed to them. For this reason beta radiation should be utilized only in an area inaccessible to personnel for a distance of several feet from the source, or where shielding material (thick plastic or thin metal) is placed between the source and the operator.

Gamma emitters present a serious shielding problem. It is probable that only large gamma sources will find eventual application because of the relatively low ionization per unit volume. With such large sources, personnel would have to be kept hundreds of yards from the eliminator, or several feet of concrete would be required for shielding. Gamma sources could be totally enclosed in rugged containers, thereby eliminating the problem of dispersal.

Radioactive static eliminators have an advantage over other types because there are no service problems — no moving parts, no wires, and no possibility of wear or snagging. Generally, they may be installed without redesign of the process machinery. With the proper choice of radioactive material, they will operate for hundreds of years.

Commercial alpha-particle eliminators have been used most extensively in paper, printing, textile and packaging processes. Dusting phonograph records, processing motion-picture film to prevent the adherence of dust, photographic enlarging and color film processing are other industrial applications. Alpha emitters have been installed to take the charge from the laminated glass of airplane windshields that may shatter under lightning-like discharges. Beta-ray eliminators utilizing strontium^{90} (one of the products of nuclear fission) and gamma-emitting cobalt^{60} (artificially produced radioisotope) have been developed and operated.

The increasing availability of large amounts of inexpensive beta and gamma-emitting materials suggests two applications of importance to the metal-processing industries. These are speculative in nature and have not yet been commercially exploited.

First is in industrial grinding operations where a very small particle size is desired. Additives or other grinding aids are commonly used for this purpose. An important function of these additives is to eliminate the static charge that builds up and prevents further grinding to finer size. The use of radioactive static eliminators to ionize the ambient air might obviate the need for additives in fine grinding.

The processing of magnesium, aluminum, and zinc metal powders presents an explosion hazard. Except when highly compressed, metallic powders are generally insulators; consequently, during normal handling in such processes as sieving, passage down a chute, or pneumatic carriage through ducts, a considerable electric charge can accumulate. The discharge of this static, either through a spark or leakage through a high resistance, may ignite the metal powder when it is in a dust cloud or in a loose heap. Ionization of the air at the sieve, along the chute, or along the free fall of the metal powder would eliminate the danger of ignition from this source.

Use of radiation for the elimination of static charges provides an effective tool for industry. The present low cost and fairly good supply of radioactive materials from atomic piles, together with a better understanding of the properties and handling of radioactivity, will make this method economically practical for many uses.

Standard Carbon Steels

Chemical Composition Limits

Revised July, 1952

Resulphurized and/or Rephosphorized Steels

A.I.S.I. Number Note (a)	Common Use Note (b)				C	Mn	P	S	S.A.E. Number
	Semi-Finished, Forging	Hot Rolled Bars	Cold Finished Bars	Wire Rods					
C 1106	–	–	√	√	0.08 max.	0.30-0.60	0.040 max.	0.08-0.13	....
C 1108	–	+	√	+	0.08-0.13	0.50-0.80	0.040 max.	0.08-0.13	....
C 1109	–	+	√	+	0.08-0.13	0.60-0.90	0.040 max.	0.08-0.13	1109
C 1110	–	+	√	+	0.08-0.13	0.30-0.60	0.040 max.	0.08-0.13	....
B 1111	–	√	√	√	0.13 max.	0.60-0.90	0.07-0.12	0.08-0.15	1111
C 1111	–	–	√	√	0.08-0.13	0.60-0.90	0.040 max.	0.16-0.23	....
B 1112	–	+	+	+	0.13 max.	0.70-1.00	0.07-0.12	0.16-0.23	1112
B 1113	–	+	+	+	0.13 max.	0.70-1.00	0.07-0.12	0.24-0.33	1113
C 1113	–	√	√	–	0.10-0.16	1.00-1.30	0.040 max.	0.24-0.33	....
C 1114	–	–	√	√	0.10-0.16	1.00-1.30	0.040 max.	0.08-0.13	1114
C 1115	–	+	+	√	0.13-0.18	0.60-0.90	0.040 max.	0.08-0.13	1115
C 1116	–	√	√	–	0.14-0.20	1.10-1.40	0.040 max.	0.16-0.23	1116
C 1117	–	+	+	+	0.14-0.20	1.00-1.30	0.040 max.	0.08-0.13	1117
C 1118	–	+	+	√	0.14-0.20	1.30-1.60	0.040 max.	0.08-0.13	1118
C 1119	–	+	+	–	0.14-0.20	1.00-1.30	0.040 max.	0.24-0.33	1119
C 1120	–	√	+	√	0.18-0.23	0.70-1.00	0.040 max.	0.08-0.13	1120
C 1125	+	+	+	–	0.22-0.28	0.60-0.90	0.040 max.	0.08-0.13	....
C 1126	+	–	–	–	0.23-0.29	0.70-1.00	0.040 max.	0.08-0.13	1126
C 1132	+	√	+	+	0.27-0.34	1.35-1.65	0.040 max.	0.08-0.13	1132
C 1137	–	+	+	√	0.32-0.39	1.35-1.65	0.040 max.	0.08-0.13	1137
C 1138	–	√	+	–	0.34-0.40	0.70-1.00	0.040 max.	0.08-0.13	1138
C 1140	–	+	+	–	0.37-0.44	0.70-1.00	0.040 max.	0.08-0.13	1140
C 1141	–	+	+	√	0.37-0.45	1.35-1.65	0.040 max.	0.08-0.13	1141
C 1144	–	+	+	–	0.40-0.48	1.35-1.65	0.040 max.	0.24-0.33	1144
C 1145	+	√	√	–	0.42-0.49	0.70-1.00	0.040 max.	0.04-0.07	1145
C 1146	–	+	+	–	0.42-0.49	0.70-1.00	0.040 max.	0.08-0.13	1146
C 1148	–	√	√	–	0.45-0.52	0.70-1.00	0.040 max.	0.04-0.07	....
C 1151	–	+	√	–	0.48-0.55	0.70-1.00	0.040 max.	0.08-0.13	1151
C 1211	–	√	√	√	0.13 max.	0.60-0.90	0.07-0.12	0.08-0.15	....
C 1212	–	+	+	+	0.13 max.	0.70-1.00	0.07-0.12	0.16-0.23	....
C 1213	–	+	+	+	0.13 max.	0.70-1.00	0.07-0.12	0.24-0.33	....

Note (a) Code for prefix letters:
B is acid bessemer carbon steel.
C is basic openhearth carbon steel.

Note (b): + sign means that this steel is more commonly specified than those with √ sign; – sign means that this steel is missing from the respective lists of standard compositions.

Notes on Silicon Content: Acid bessemer steels (Code B) are not produced with specified silicon content. (Normally silicon is very low — 0.01 to 0.02%.)

C 10xx steels — When silicon is required the following limits are commonly specified for semi-finished bars for forging, and hot rolled and cold finished bars:

C 1005 to C 1013..... 0.10% max.

C 1015 to C 1025..... { 0.10% max. / 0.10 to 0.20% / 0.15 to 0.30% }

C 1026 to C 1095..... { 0.10 to 0.20% / 0.15 to 0.30% }

Wire rods of all C 10xx analyses may be specified as noted above for C 1015 to C 1025.

C 1106 to C 1111 for hot rolled and cold finished bars may be limited to 0.10% max. when silicon is required. All other steels of C 11xx series in the standard lists may be specified as follows: 0.10% max., 0.10 to 0.20%, or 0.15 to 0.30%.

C 1211, C 1212 and C 1213 are not commonly produced to specified limits for silicon.

Note on Copper Content: When required, copper is specified as an added element to a standard steel.

Note on Variations: Chemical analyses are subject to standard variations for check analysis shown in Sections 2, 8, 9 and 15 of the American Iron & Steel Institute's "Steel Products Manual".

Basic Openhearth and Acid Bessemer Carbon Steels

A.I.S.I. Number Note (a)	Semi-Finished, Forging	Hot Rolled Bars	Cold Finished Bars	Wire Rods	C	Mn	P Max.	S Max.	S.A.E. Number
C 1005	–	–	√	+	0.06 max.	0.35 max.	0.040	0.050	....
B 1006	–	–	√	+	0.08 max.	0.45 max.	0.07-0.12	0.060	....
C 1006	–	+	√	+	0.08 max.	0.25-0.40	0.040	0.050	1006
C 1008	–	+	√	+	0.10 max.	0.25-0.50	0.040	0.050	1008
B 1010	–	+	√	√	0.13 max.	0.30-0.60	0.07-0.12	0.060	....
C 1010	+	+	+	+	0.08-0.13	0.30-0.60	0.040	0.050	1010
C 1011	–	+	√	–	0.08-0.13	0.60-0.90	0.040	0.050	....
C 1012	+	+	√	+	0.10-0.15	0.30-0.60	0.040	0.050	....
C 1013	–	–	√	+	0.11-0.16	0.50-0.80	0.040	0.050	....
C 1015	+	+	√	+	0.13-0.18	0.30-0.60	0.040	0.050	1015
C 1016	+	+	+	+	0.13-0.18	0.60-0.90	0.040	0.050	1016
C 1017	+	+	√	+	0.15-0.20	0.30-0.60	0.040	0.050	1017
C 1018	+	+	+	+	0.15-0.20	0.60-0.90	0.040	0.050	1018
C 1019	–	√	+	+	0.15-0.20	0.70-1.00	0.040	0.050	1019
C 1020	+	+	+	+	0.18-0.23	0.30-0.60	0.040	0.050	1020
C 1021	+	+	√	–	0.18-0.23	0.60-0.90	0.040	0.050	1021
C 1022	+	+	+	+	0.18-0.23	0.70-1.00	0.040	0.050	1022
C 1023	–	+	√	–	0.20-0.25	0.30-0.60	0.040	0.050	....
C 1024	–	+	+	–	0.19-0.25	1.35-1.65	0.040	0.050	1024
C 1025	+	+	+	√	0.22-0.28	0.30-0.60	0.040	0.050	1025
C 1026	+	+	+	–	0.22-0.28	0.60-0.90	0.040	0.050	1026
C 1027	–	√	√	–	0.22-0.29	1.20-1.50	0.040	0.050	1027
C 1029	+	+	√	–	0.25-0.31	0.60-0.90	0.040	0.050	....
C 1030	+	+	+	+	0.28-0.34	0.60-0.90	0.040	0.050	1030
C 1031	+	–	–	–	0.28-0.34	0.30-0.60	0.040	0.050	....
C 1032	+	+	√	–	0.30-0.36	0.60-0.90	0.040	0.050	....
C 1033	–	√	√	√	0.30-0.36	0.70-1.00	0.040	0.050	1033
C 1034	–	–	√	√	0.32-0.38	0.50-0.80	0.040	0.050	1034
C 1035	+	+	+	+	0.32-0.38	0.60-0.90	0.040	0.050	1035
C 1036	–	√	√	–	0.30-0.37	1.20-1.50	0.040	0.050	1036
C 1037	–	+	√	–	0.32-0.38	0.70-1.00	0.040	0.050	....
C 1038	–	+	+	+	0.35-0.42	0.60-0.90	0.040	0.050	1038
C 1039	–	+	√	–	0.37-0.44	0.70-1.00	0.040	0.050	1039
C 1040	+	+	+	+	0.37-0.44	0.60-0.90	0.040	0.050	1040
C 1041	–	√	√	+	0.36-0.44	1.35-1.65	0.040	0.050	1041
C 1042	+	+	+	–	0.40-0.47	0.60-0.90	0.040	0.050	1042
C 1043	+	+	√	–	0.40-0.47	0.70-1.00	0.040	0.050	1043
C 1045	+	+	+	–	0.43-0.50	0.60-0.90	0.040	0.050	1045
C 1046	+	+	√	–	0.43-0.50	0.70-1.00	0.040	0.050	1046
C 1049	+	+	+	–	0.46-0.53	0.60-0.90	0.040	0.050	1049
C 1050	+	+	+	–	0.48-0.55	0.60-0.90	0.040	0.050	1050
C 1051	–	–	√	+	0.45-0.56	0.85-1.15	0.040	0.050	....
C 1052	–	√	√	–	0.47-0.55	1.20-1.50	0.040	0.050	1052
C 1053	–	√	√	–	0.48-0.55	0.70-1.00	0.040	0.050	....
C 1054	–	–	√	+	0.50-0.60	0.50-0.80	0.040	0.050	....
C 1055	–	+	√	–	0.50-0.60	0.60-0.90	0.040	0.050	1055
C 1057	–	–	√	+	0.50-0.61	0.85-1.15	0.040	0.050	....
C 1059	–	–	√	+	0.55-0.65	0.50-0.80	0.040	0.050	....
C 1060	–	+	√	+	0.55-0.65	0.60-0.90	0.040	0.050	1060
C 1061	–	–	√	√	0.54-0.65	0.75-1.05	0.040	0.050	....
C 1062	–	–	√	+	0.54-0.65	0.85-1.15	0.040	0.050	1062
C 1064	–	–	√	+	0.60-0.70	0.50-0.80	0.040	0.050	1064
C 1065	–	√	√	–	0.60-0.70	0.60-0.90	0.040	0.050	1065
C 1066	–	–	√	+	0.60-0.71	0.85-1.15	0.040	0.050	1066
C 1069	–	√	√	+	0.65-0.75	0.40-0.70	0.040	0.050	....
C 1070	–	+	√	–	0.65-0.75	0.60-0.90	0.040	0.050	1070
C 1071	–	–	√	√	0.65-0.76	0.75-1.05	0.040	0.050	....
C 1072	–	√	√	–	0.65-0.76	1.00-1.30	0.040	0.050	....
C 1074	–	–	√	+	0.70-0.80	0.50-0.80	0.040	0.050	1074
C 1075	–	√	√	√	0.70-0.80	0.40-0.70	0.040	0.050	....
C 1078	–	+	√	√	0.72-0.85	0.30-0.60	0.040	0.050	1078
C 1080	+	+	√	–	0.75-0.88	0.60-0.90	0.040	0.050	1080
C 1084	–	+	√	–	0.80-0.93	0.60-0.90	0.040	0.050	....
C 1085	–	+	√	–	0.80-0.93	0.70-1.00	0.040	0.050	1085
C 1086	–	√	√	–	0.82-0.95	0.30-0.50	0.040	0.050	....
C 1090	–	√	√	–	0.85-0.98	0.60-0.90	0.040	0.050	1090
C 1095	+	+	+	+	0.90-1.03	0.30-0.50	0.040	0.050	1095

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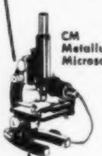

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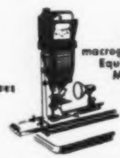

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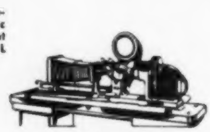

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By W. A. Maxwell and Paul F. Sikora, Members of Technical Staff, Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics, Cleveland

Stress-Rupture and Creep Testing of Brittle Materials

IN AN EFFORT to conserve critical materials and increase operating temperatures, several ceramics and ceramals are being investigated at the N.A.C.A.'s Lewis Laboratory for possible use in turbine blade and other high-temperature applications in which components are subject to severe continuous stress. For such uses, the long-time properties, stress-rupture strength and creep are criteria for the evaluation of new materials. Therefore, considerable attention has been devoted to the development of convenient techniques for determining these properties. Although actual data cannot yet be given for the materials tested, the apparatus and methods of testing are of interest.

Most of the problems encountered when testing ductile alloys — such as furnace design, instrumentation, and temperature gradients — are also encountered when testing brittle materials. The most important new difficulty is alignment of the specimen to prevent failure in bending; a small misalignment which could be ignored in metallic alloys is fatal to a brittle material. Solution of this problem is possible by one of three methods.

The first method requires careful prealignment of the specimen in precisely machined and adjusted grips. The assembly could be checked at room temperature by using strain gages but no positive assurance exists that room-temperature conditions would be maintained during high-temperature testing. Experience at the Lewis Laboratory has shown the method to be satisfactory, although laborious and time-consuming, for short-time tensile testing.*

The two other methods depend on alignment by deformation or cushioning of some portion of the gripping mechanism. Since the brittle material cannot deform plastically to alleviate bending stress, the corrective deformation would be made to take place in the grips holding the specimen. This principle can be applied by two methods. One requires a comparatively long specimen so the grips or holders remain outside the furnace. The specimen can then be seated in a material which is plastic at room temperature (or at least below test temperature). A method as developed at Ohio State University[2, 3] appears quite attractive, especially for test temperatures above 2000° F.

Our method uses a comparatively short specimen completely in the furnace and held in grips of a material having sufficient plasticity at the test temperature to assure alignment. The specimen is aligned at room temperature and a small pre-load draws it into position during heating to test temperature. An advantage of this method is that a comparatively small specimen may be used, which is an important consideration when materials to be tested are available only in laboratory quantities and are fabricated by laboratory methods. Also the method closely resembles the conventional test techniques commonly used for high-temperature alloys.

The greatest difficulty with this method is in the selection of a grip material. The high-temperature alloys, especially the more machinable ones, have high creep rates at 2000° F., and failure of the grips might result from excessive creep. On the other hand, the higher the creep rate, the greater the cushioning effect for alignment will be. Experiment showed that the creep rate of

*1. "Initial Investigation of Carbide-Type Ceramal of 80 Per Cent Titanium Carbide Plus 20 Per Cent Cobalt for Use as Gas Turbine Blade Material", by C. A. Hoffman, M. G. Ault and J. J. Gangler, N.A.C.A. TN 1836.

2. "Equipment for Processing and Testing Cermet Solid Bodies", by A. R. Blackburn and T. S. Shevlin, Ohio State University Research Foundation Project 252 (341), Report No. 50, A.A.F. Contract W33-038-ac 14217.

3. "A Tensile Test Machine for Brittle Materials", by H. R. Lowers, Ohio State University Research Foundation Project 252 (341), Report No. 36, A.A.F. Contract W33-038-ac 14217.

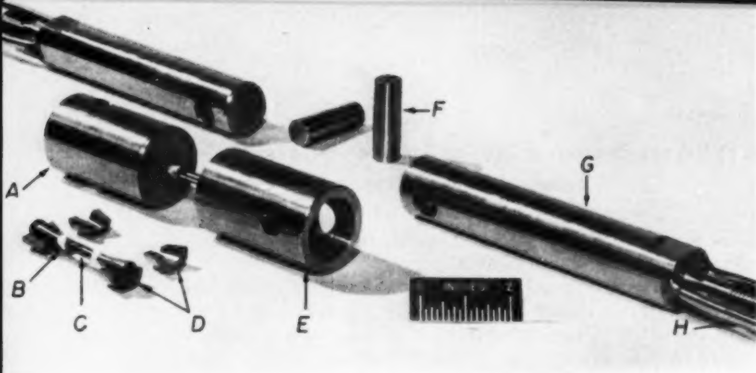


Fig. 1 — Elements of Gripping Mechanism
A — Specimen mounted in holders
B — Platinum extensometer
C — Specimen; D — Inserts
E — Holders; F — Pins
G — Air-cooled pull rods
H — Cooling air lines

an alloy such as Inconel "X" was sufficient for cushioning but not so great as to cause failure of the holders at the highest stresses used in our test program.

Grips and accessories are shown in Fig. 1. All parts are machined from annealed Inconel "X". Split wedges (inserts) attach the specimen to sleeve-like holders. Holders are joined to pull rods by large pins. To minimize creep in the pull rods, they are air cooled, an effect which probably does not extend further than the upper surface of the pins.

Specimens have been used in lengths from 3 to 4 in., usually 3½ in., with a gage diameter of 0.250 in. and length of 1¼ in. The conical ends, which have a 10° angle, eliminate threading and increase the ease of fabrication and mounting. The small gage diameter reduces the stress in the holders but also increases the surface-to-mass ratio; however, it might be argued that the surface-to-mass ratio for stress-rupture specimens should be comparable with that of the actual component for which the material is intended, and the J-33 jet engine turbine blade has a ratio of surface to mass comparable to the ¼-in. diameter specimen.

Platinum extensometers are used, such as described by Fellows, Cook and Avery in their article "Precision in Creep Testing", *Transactions*, A.I.M.E., Vol. 150, 1942, p. 358. This extensometer consists simply of a rod and a tube affixed to the specimen with cement. The rod slides within the tube and creep is measured by the change in distance between marks on these two platinum parts. Equipment assembly, and telescope used to measure the elongation, are shown in Fig. 2.

A precision of 0.001 cm. in 1-in. gage length (or about 0.04%) is obtained. The glow of the hot furnace is quite adequate for viewing the extensometer at 1800 and 2000° F. However, at 1600° F. the furnace is much too dark for convenient readings. It was discovered that if a small quartz rod was inserted obliquely through the furnace wall, it would carry the light of a flashlight bulb at the outer end of the quartz rod sufficiently to illuminate the inside of the furnace brilliantly.

As mentioned previously, the creep of the Inconel holders is both an advantage and a disadvantage. In any event, this creep is large enough to drop the beam, yet the beam must be kept level to avoid bending the specimen and changing the actual load applied.

The total extension along the specimen axis, due to creep and thermal expansion, is from 0.25 to 0.50 in. or more. Since hand methods for correcting this extension are rather rough, both in regard to time intervals and violence to the specimen, it became apparent that an automatic leveling device was necessary. As shown in Fig. 2 at left foreground this consists of a rather complex gear train having a stepdown of 18,000 to 1. The gear train is connected through the drive screw to the lower pull rod and is driven by a reversing electric motor, actuated by microswitches which contact the beam at top or bottom as it rises or falls. With this arrangement a drop in the beam due to a change of 0.001 in. in length on the specimen axis will be automatically corrected. The speed of motion on the specimen axis is approximately 0.003 in. per min.

Probably the most important technique in what might be called the creep-cushioning method is proper preloading of the specimen. General practice is to apply a stress of approximately 2000 psi. and to maintain this stress while the specimen is being heated to the test temperature and for a 1-hr. soak period thereafter. Since a conventional platinum-wound tube furnace is used, this heating period usually extends overnight. Once the system is at 2000° F., the remainder of the load is applied in 4000-psi. increments at 15 to 20-min. intervals. At

lower temperatures the plasticity of the grips is less and the loading rate is more critical; several hours are required to apply high loads at 1600° F. While this preloading appears essential for alignment, it has some tendency to obscure first-stage creep.

What happens to a set of grips after repeated tests at 1800 to 2000° F.? After 2000 to 3000 hr. at these temperatures the flat tops of the conical inserts have bulged upward into a considerable dome, and the inboard surface of the holders is no longer flat. Despite this deformation these inserts and holders are probably as satisfactory for use as a new set and are good for considerable life. The pins have bent so much they will be discarded, but fortunately they are the most easily fabricated component.

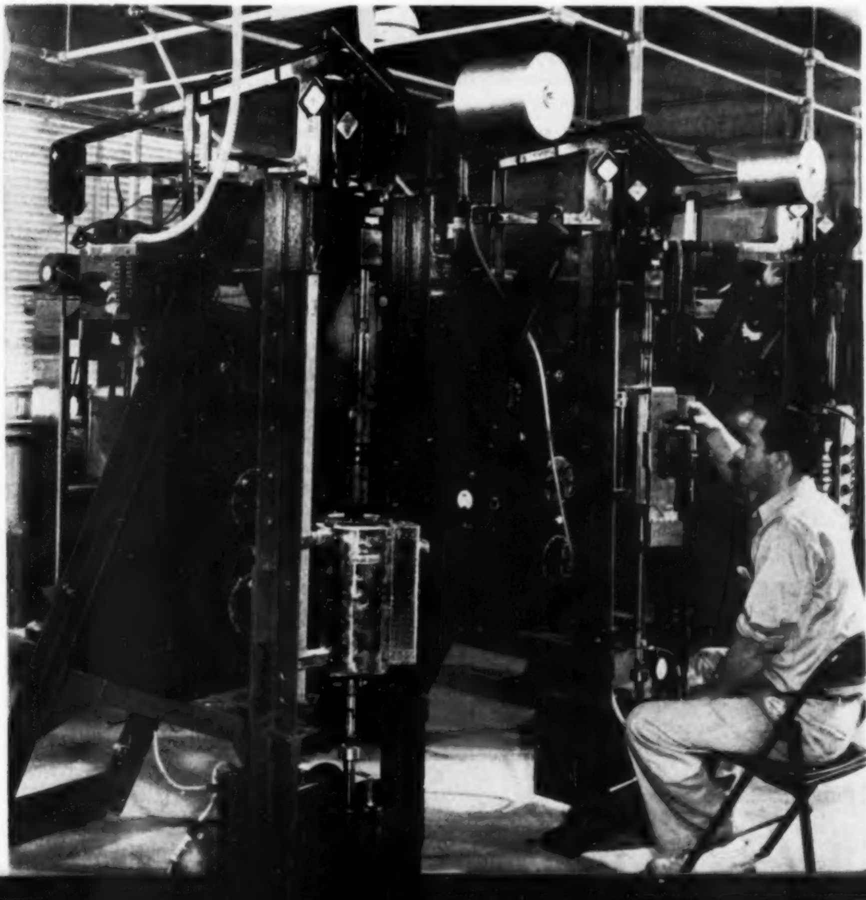
The limitations as regards stresses and times at given temperatures can best be shown by a tabulation. In the last column are given the times for which the method is

Temperature	Stress	Life
1600° F.	25,000 psi.	2000 to 10,000 hr.
1800	10,000	1200 to 5000
	20,000	200 to 1000
1900	10,000	300 to 1000
	15,000	85 to 500
2000	7,500	150 to 750
	15,000	20 to 150

believed suitable; the minimum has in each instance been exceeded by actual tests and the maximum is an estimated value.

To Summarize: Consistent data have been obtained with this method and the limited scatter of individual determinations has indicated the validity of the results. A specimen has yet to break in the grips, and there has been no failure which would be attributed to misalignment. Thus, a convenient method for stress-rupture determinations on brittle materials has been developed to the point where it can be recommended to those interested in the problem.

Fig. 2 — Gear Train for Automatic Compensation of Creep in Specimen and Telescope for Measuring Elongation



By Alfred Clift, Department of Research and Technical Development
Stewarts and Lloyds, Ltd., Bilston, Staffordshire, England

Protection of Tubular Structures From the Weather by Metallizing

The rapid recent development in Britain of steel structures made of tubular members can be attributed to advances in welding techniques, and to the fact that welded and seamless tubes of carbon steel and high-tensile steel are available in a wide range of sizes. Ordinary structural shapes may not be used in thin sections due to possible loss of metal by corrosion and to the necessity for stiffness. These restrictions do not apply in the same degree to tubular sections, as they are by virtue of their shape much stiffer than open rolled sections and consequently less liable to handling and transport injuries. This, coupled with the better local buckling and torsional resistance, gives the tubular section decisive advantages. Where wind stresses govern the design, as for instance in towers and masts, the smaller exposed areas are also of considerable importance. Welded tubular steel structures thus combine strength and rigidity with the advantages of light weight, small surface area and a clean appearance.

This paper, however, is not so much concerned with the design aspect as with the protection of such structures against atmospheric corrosion. In this respect, the smooth, rounded surfaces and the absence of sharp projections and spaces difficult of access facilitate painting operations and give longer life to the coating.

Fears have been raised as to the dangers of *internal* corrosion of tubular members, since usually they are not large enough to inspect and maintain. In my experience, however, no corrosion takes place in a sealed tube, since all the usual corrosion agents present in the atmosphere are absent or insufficient in quantity. Sealing of all tubes, even by the addition of welds otherwise superfluous, is therefore a basic part of the technique developed by Stewarts and Lloyds.

Steel structures may be installed in reasonably dry sheltered positions, such as roof trusses in houses, or they may be exposed to highly corrosive industrial atmospheres. While a great variety of protective treatments may be applied, painting is the simplest form of protection that can be applied after fabrication. Much study has been given to the painting operation, and it has been shown that surface preparation is the most important factor.

It is generally accepted that mill scale can considerably shorten the protection afforded by paint. Nevertheless, it is not always easy to remove from ordinary structural shapes. As will appear in this article, mechanical equipment handles this matter neatly for tubes.

Experience fortifies the results of our own tests, and shows that descaled surfaces, subsequently painted, not only give longer life before visible corrosion appears, but level out the performance of various paints to such an extent that a much wider range of primers may be used, some costing considerably less than others often specified.

Whether or not the steel is descaled beforehand, there is always the possibility of accidental damage by subsequent handling. If such damaged areas are not observed, local rusting may occur before routine maintenance painting. Nevertheless, where proper attention can be given during and after erection, and damaged spots retouched, painting can be a very satisfactory form of protection, particularly if applied to a properly descaled surface.

Protection of Structures by Metal Coating

Articles or subassemblies made in mass production, and handled or stored after painting, are likely to be damaged mechanically, and it may be necessary to consider a

more robust form of protection such as that afforded by metal coating.

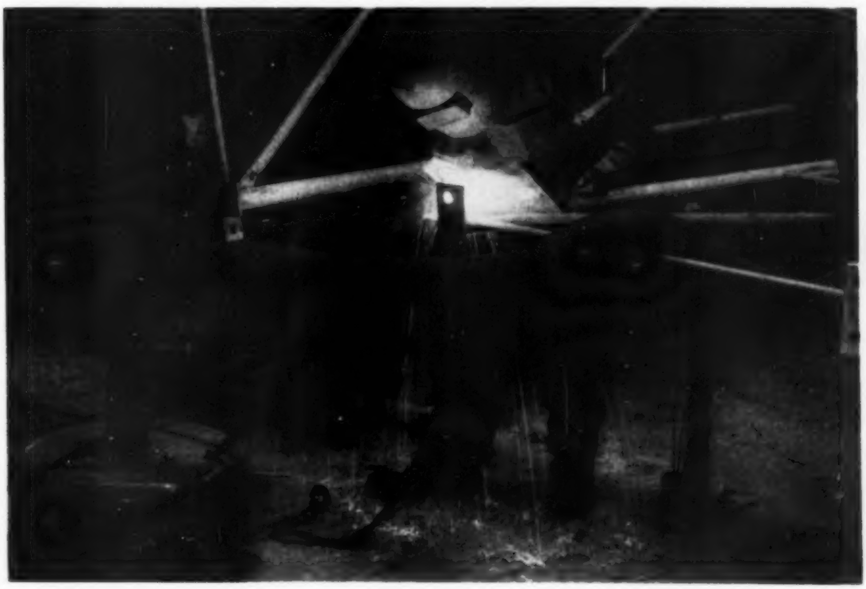
Hot dip galvanizing has been used extensively in Britain for this purpose for many, many years. Galvanizing is naturally limited to sizes and shapes of finished assemblies which can be accommodated by the available tanks. This can be overcome by protecting the component tubes in straight lengths before fabrication, and afterward repairing any damage that may be sustained, particularly at welded joints, by metal spraying with a hand gun. Much can be said for this technique; the stock components can be stored (even out-of-doors in a protected condition) until such times as they are required for fabrication. No difficulties have been experienced in producing sound joints on galvanized tubing by electric welding, using the same technique as for ordinary unprotected mild steel. The zinc oxide fumes, which may be objectionable, are extracted by the arrangement shown in Fig. 1.

After welding, the joints can best be protected by metal spraying. Sprayed metal is normally applied only to surfaces which have previously been grit or shot-blasted; while this gives the best results, it is not necessary where only "touching up" is required. Adjacent areas of good surface can be protected by masking with adhesive or common electrician's tape before blasting the joints. I have found, however, that welded joints in galvanized tubing can be given a good measure of protection by spraying zinc with a portable "metallizing" gun without prior shot-blasting, providing the joints are first carefully chipped and scratch-brushed and preheated to a temperature of about 300° F. by flame or otherwise. The coating over the weld should be at least 0.005 in. thick, to give protection equivalent to the adjacent hot-dip coating of about 2 oz. per sq.ft. A large spread of coating is unnecessary, for while this will adhere tightly to the old coating at the edge of the joint which has been roughened or partly damaged by the welding heat, it is less firmly adherent to the undamaged galvanized surface further away from the joint. This wasteful spread of sprayed metal coating can be reduced to a minimum by holding the spray gun close, say 2 to 3 in. distant from the joint.

An additional sealing line of zinc-rich paint can also be applied to the junction between the sprayed metal coating and hot dip galvanizing.

Welds on galvanized tubing, treated in

Fig. 1 — Fume Extractor in Use When Welding Galvanized Tubing



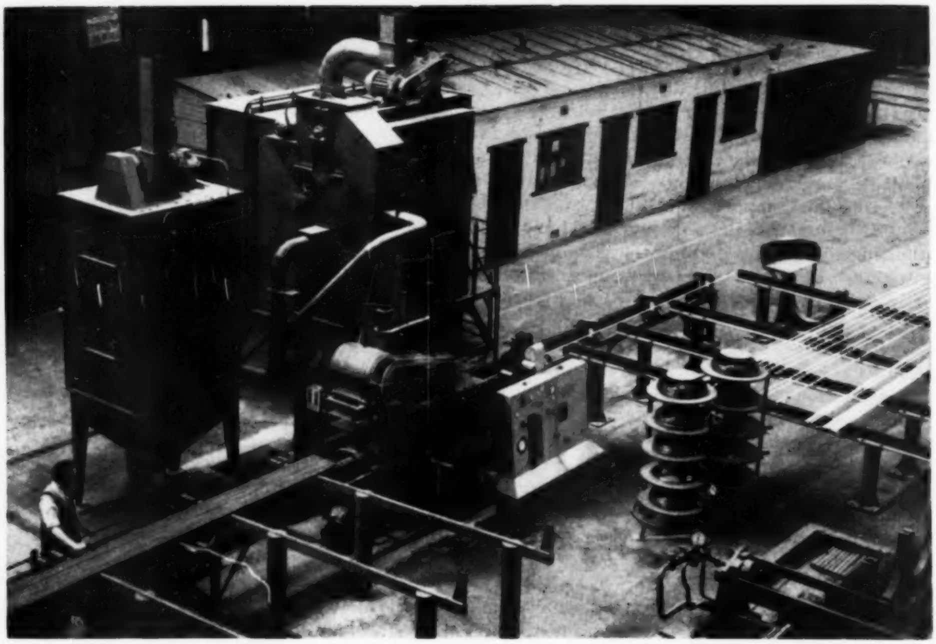
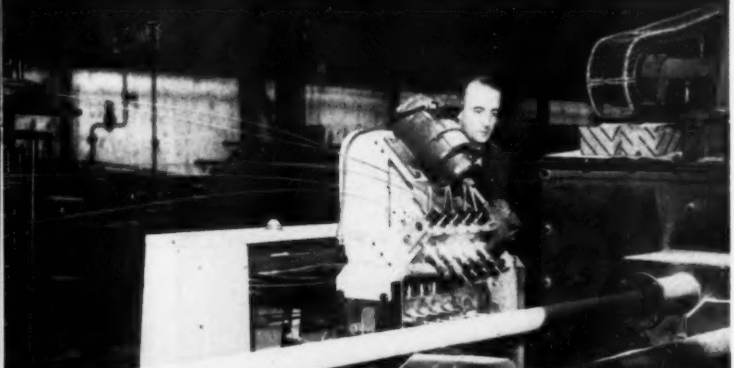


Fig. 2 — General View of Plant for Grit-Blasting Straight Lengths of Tubing and Metallizing With Either Zinc or Aluminum. "Wheelabrator" in middle ground, dust arrester at left behind man at feed table. Coils of wire for metallizer in right foreground and run-out table beyond

Fig. 3 — A 2½-In. Tube Is Emerging From the Grit-Blaster and Is Being Sprayed, as It Rotates, With Metal From Ten Burners



this manner, have been in use, exposed to a wide variety of atmospheric conditions, for several years with no signs of failure.

Another approach to the problem has been made in our organization by the development of a semi-automatic process for treating the outside surface of straight lengths of tube by spraying with either zinc or aluminum, and a machine for this purpose has recently been built by Metallisation Ltd., Great Britain. A general view of this installation is shown in Fig. 2. Figure 3 is the exit side of the cleaner and metallizing machine.

The machine consists essentially of a "Wheelabrator" grit descaler in line with two banks of metal-spraying burners. The tubes

are fed through the machine by power-driven rolls, rubber-tired, which rotate the tube and convey it slowly through the unit.

The coating metal is fed into the spray heads in the form of ⅛-in. wire of zinc or aluminum. Each of the ten burners has an oxy-coalgas flame; the molten metal is atomized and blown on the steel surface by a jet of compressed air. A close-up of this unit is shown in Fig. 4.

In the Wheelabrator unit, steel grit is fed to an impeller wheel from which it is thrown by centrifugal force against the surface of the rotating tube. The separating, cleansing and conveying gear for the frit is conventional for this type of equipment.

The speed of advance of the tube is governed by the angularity of the drive rolls, and with the existing machine a through-put of 28 ft. per min. is possible.

Descaling and spraying units are in close proximity so that the surface is sprayed immediately after it is cleaned. The existing machine has been successfully used for tube sizes between ¾ and 3 in. diameter, though with the small sizes only one bank of burners is employed. "Overspray" normally does not exceed 10%, and this can be recovered.

Once the machine is started, the process is automatic except for labor at loading and unloading tables. Lengths are limited only by the available handling facilities. Using 2-in. tubes in 20-ft. lengths and aluminum wire in 28-lb. coils, some 400 tubes can be sprayed continuously with a 0.004-in. coating.

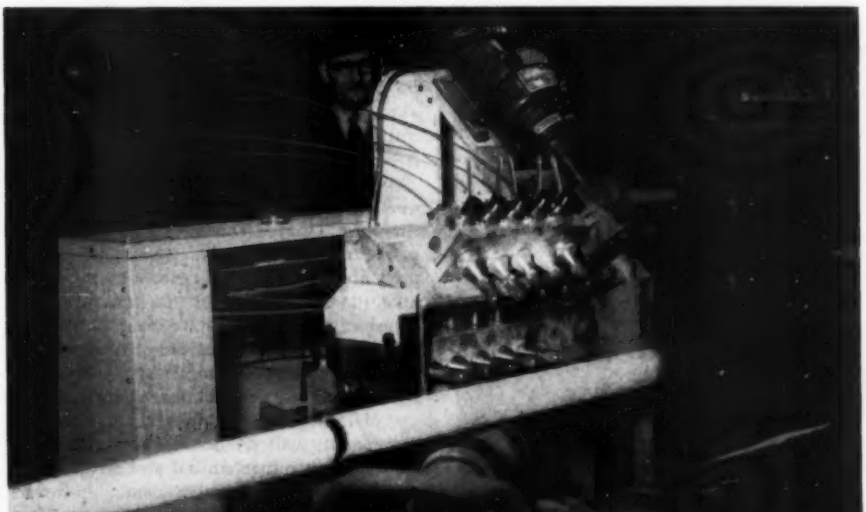
Descaling by grit-blasting is an essential preliminary treatment of cold steel surfaces, since sprayed metal depends for adhesion on physical interlocking with a roughened surface. This condition is illustrated by Fig. 5 on the next page.

A little difficulty was at first encountered in welding aluminum coated tubes, and early attempts using the same technique as for ordinary hot rolled tubing produced a rough deposit having a gassy appearance. This difficulty can be overcome by certain brands of electrodes; one which gave good results is "Lincoln L. H. 70".

After welding, the joints can be spray coated, in much the same way as described above for galvanized structures, after first cleaning and preheating. However, if the original units have been protected by metal spray, a hand-sprayed coating over the weld will adhere very firmly to the original undamaged coating on each side of the joint.

Because of minor irregularities on the

Fig. 4 — Spray Flames in Operation. One tube is closely followed by the next



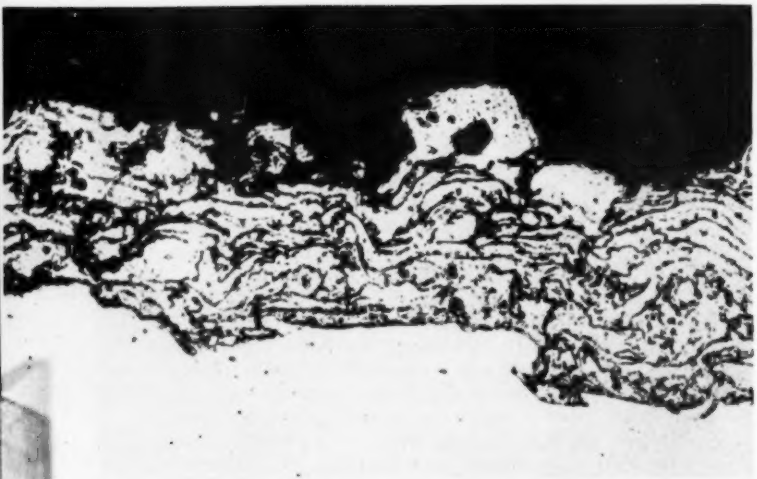
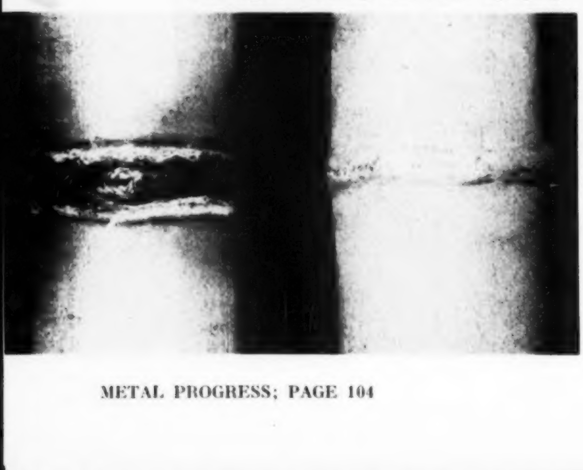


Fig. 5 — Laminated Layer of Aluminum, Sprayed on a Grit-Blasted Steel Surface, Which Provides a Key for the Coating

surface, it is necessary to have about 0.005 in. of aluminum over joints to give equivalent protection to the 0.004-in. coating laid on by the automatic equipment. Welds treated in this manner behave quite satisfactorily. A welded joint after hand spraying with aluminum is shown in Fig. 6.

Cost — The cost of mechanical spraying with aluminum is about 75% of the cost of painting one coat with zinc-rich paint or hot-dip galvanizing to a similar coating thickness, and runs only about 25 to 30% more than painting with one coat of red lead primer followed by one coat of bitumen paint.

Fig. 6 — A Proper Butt Weld Damages a Very Small Amount of Aluminum Coating, and It Can Be Readily Repaired by Wire Brushing, Preheating and Hand Spraying



Service — Sprayed aluminum coatings tend to show marked porosity at thicknesses less than 0.004 in. For this reason, mechanical spraying with its more even thickness of coating is much to be preferred over hand spraying for the main structure. Porous aluminum coatings show rust stains on exposure to weather — within two days in a moist, industrial location — but, generally speaking, the pores rapidly seal up. With coatings 0.004 in. thick or thicker, the article can be used several years without deterioration before paint is applied, and owing to the grit-blasted surface on which the metal is sprayed, adhesion of the paint is excellent.

Zinc sprayed coatings do not show the same tendency for rust staining, presumably owing to sacrificial protection provided by this metal. Sprayed zinc has a somewhat superior ability to withstand distortion.

While it is not always possible or even desirable for a complete and final protection to be applied by the fabricators, it is nevertheless essential that steel structures should be adequately treated before leaving the shop, not only to resist rusting and corrosion until erection on site, but also to provide a good surface for the final coat.

Thus, metallic coatings alone will frequently give all the protection required, yet they can also be considered as permanent primers for paint coats. The metal primer prevents rusting, which would otherwise take place when the paint film begins to deteriorate. Thus, not only is repainting less frequently required, but the absence of rust simplifies this operation, resulting in a general reduction in maintenance costs.

Metallic coatings on structural steel components will no doubt be promoted by the use of such mechanized processes. Their economical employment depends, however, on the amount of retouching necessary after fabrication into the completed structure on the building site.

Comments on Dilastrain Method

NEW YORK CITY

Upon reading the article "Dilastrain Method for Determining Endurance Limit of Materials" which appeared in *Metal Progress* for February, the words of Dr. Langmuir come to one's mind, "You can't plan to make discoveries. But you can plan work that will probably lead to discoveries. . . . You don't know all the things that are going to happen; too many of them are unexpected. But it is these unexpected things that are going to be the most profitable — most useful — things you do." The work that is described in this article by Rosenholtz and Smith may very well open up a new field in materials research and stress analysis, and may change some of our basic concepts.

One of the first questions which requires considerably more study (and which was pointed out by the authors) is the effect of fatigue testing machines on the properties determined. Scattering of test points is one of the chief reasons that makes fatigue testing a tedious and time-consuming task. This problem becomes even more conspicuous when different types of testing machines have been employed. In the current study the authors have been using the Sonntag machine exclusively. If the measuring method is as sensitive and foolproof as the authors claim, it may finally lead to a more basic determination of size, speed, and temperature effects, in addition to differences due to testing machines.

It is said this method is not confined to axial loading, but torsion, bending and combined stresses may be studied. This point is not very clear because the principle of measuring is based on a sudden change in the coefficient of thermal expansion, affected by change in the atomic lattice. How can this be applied to a combined stress analysis?

From the testing technique as presented in the paper, it appears that a preliminary testing series is required to determine approximately the S-N curve. It may happen in many applications, especially where the design calls for finite life, that this preliminary study is all that is required, unless the α-S curve can be extended to stress levels other than the fatigue limit. This brings up another important consideration requiring further additional experimental data, namely, which sets of data are more precise, the α-S curve or the S-N curve? Secondly, which quantitative determination requires greater laboratory skill, α or N?

The article points out that the machining tolerances and surface temperature during machining of the specimens are a critical factor; however, the surface condition is also claimed to be less important than in conventional fatigue testing. This appears somewhat incongruous, since the stressings of the specimens are performed in conventional machines and the Dilastrain apparatus merely records the concomitant physical changes.

Correspondence

The most challenging parts of the paper, and probably the least substantiated, were the new definitions for proportional limit, yield point, ultimate strength and fatigue limit, which are appended by the prefix "true". Although the authors may have had some physical basis for their statements, these appear rather arbitrary and confusing, especially the lax and apparently interchangeable use of the terms proportional limit, yield point and yield strength, fatigue limit and fatigue strength. (See "Manual on Fatigue Testing", A.S.T.M. Special Technical Publication No. 91, 1949.)

The authors give some experimental values as determined by the Dilastrain method for the endurance limit in torsion and bending. The computed ratios of the torsion-to-bending are compared with "theoretical values" and show good agreement. Unfortunately, the values refer to a theory dealing with the yielding of metals under certain well defined conditions, but to relate fatigue limits with yield values is very questionable because the fatigue limits may be above or below the yield point (as the authors themselves stated it).

This research is a significant step toward a new approach in the mechanics of materials, and the authors should be congratulated on their excellent work.

NICHOLAS GROSSMAN
Mechanical Engineer
The M. W. Kellogg Co.

Not as Quoted

MELBOURNE, AUSTRALIA

In the excellent paper by Thomas J. Dolan which appeared in *Metal Progress* for March 1952 ("How Can We Appraise Metals for High-Temperature Service?"), there appeared a reference to a paper of mine on a related subject: "Fatigue Problems in the Gas-Turbine Aero Engine" (Symposium on the Failure of Metals by Fatigue, Melbourne University Press, 1946, p. 383).

I was quoted to have said that some Australian machines had been built to imitate the complex fatigue stressing which occurs in the rotor blading of gas-turbine engines. In actual fact, these machines were designed and built in England, as stated in my paper. Australian developments in the field of high-temperature fatigue are at present restricted to machines which apply simple alternating bending.

May I add that Professor Dolan's warning concerning the interaction between cycle-dependent fatigue and time-dependent creep is both timely and important at this stage when designers are asking for ever-higher performance in turbine materials.

A. R. EDWARDS
Aeronautical Research Laboratories

How to Select Research Projects

PITTSBURGH

Research by its very nature can not be tailored to any set pattern, and methods for selecting research projects will naturally present different problems to different organizations. Certainly a clear-cut statement of company policy by top management concerning the hopes and aims to be realized by research for new products and processes is extremely important in expediting the choice of projects for future selection. Without a clear-cut policy or understanding, the selection of research projects starts on a weak foundation.

Then, too, any plan for choosing research projects must be sufficiently elastic to take care of emergencies which may arise. In other words, the plan must not be so detailed that it becomes a "red tape" procedure, yet it must secure essential information.

I think that this problem of determining the areas of desirable research is a very heavy responsibility. I believe that far too many projects are almost certainly the ones which will too frequently result in unsatisfactory returns to any company. Thus I believe it should be recommended that certain preliminary investigations be made fundamental prerequisites for the securing of essential data upon which to base the choice.

It would seem that the chronological order for these prerequisite investigations would be as follows:

1. Exploratory research.
2. Literature survey.
3. Executive investigation, including a sales survey.

Any emergency may change this sequence. It would appear, however, that the first two steps should precede the third step, since if the early steps will render the project impossible, then the succeeding steps are unnecessary. Always, of course, the project chosen should be thoroughly investigated to determine whether or not it coincides with the present or future activities or plans of the company.

W. F. ROCKWELL, JR.
President
Rockwell Mfg. Co.

Opinion of U. S. Industry

KNAPSACK BEZ. KÖLN, GERMANY

I thank the A. S. M. and the American industry for the magnificent reception and assistance we received during the study tours and the World Metallurgical Congress. I will often remember the beautiful and interesting days we were allowed to spend in your country and to have at least a glimpse of the life in the States that is so different from ours.

It is not possible for us to copy exactly your methods of manufacturing. Although we are a highly industrialized country as far as numbers of factories are concerned, we certainly do not have your high production per factory. In our country there are a lot of specialized workers, representing more than 30 vocations. These people undergo an apprenticeship of three years and then must pass an examination to become journeymen. These specialized workers are of the greatest advantage to us because we can expect work of high standard from them even if the process of manufacturing is not mechanized. They also make it possible for us to change the methods of manufacturing relatively fast by adaptation of existent

equipment. Consequently our industry is not as interested in specialized machines as in universal machines which can be used for many purposes. So it is possible, in spite of our small volume of production, to achieve an economical method of manufacturing because the plant is not burdened by the amortization of expensive equipment.

We are interested in some of the processes we observed in your factories and these are being investigated to learn whether they hold enough merit to be adopted. Maybe you will question the wisdom of such tests and wonder why we should not immediately introduce the processes derived from our American experiences. Please remember that in our country almost all products have to be approved by the authorities. Therefore it is necessary to prove to them that the application of a new process results in a product of unquestionable quality. Only then can the new method be adopted.

HANS VON HOFE
Scientific Cooperator
Beratungsstelle für Autogen-Technik Ev.

Concerned With Fate of HCN Makers

SOUTH BEND, IND.

I read with interest the article in the June 1952 issue of *Metal Progress* entitled "An Improved Cell for Electrolytic Polishing". A statement appears in the article as follows: "The electrolyte originally consisted of 0.5% $AuCl_3$ solution plus 15% KCN, but investigation led to the conclusion that dilute HCl plus 10% KCN worked as well."

Below the authors' names is the notation: Professor Gleekman *was formerly* a graduate student, Dr. Evans *was* assistant professor of Chemistry and Professor Grove *was* head of chemical engineering . . . !

Did these gentlemen find out too late that the above combination produces the deadly poisonous HCN?

HAROLD WIESNER
Research Chemist
Bendix Products Division
of Bendix Aviation Corp.

These HCN Makers Among the Living

NEWARK, DEL.

The authors acknowledge the verity of the chemical reaction, as Mr. Wiesner points out. They wish to point out that, while it is true that they *were* associated at the University of Iowa, the fact that they *are* now at their current positions should indicate that due regard for personal safety was observed. The electrolytic polishing and etching was carried out under a hood.

Incidentally, the auric chloride plus 10% KCN solution, under conditions of electrolysis, produces HCN.

A fundamental rule for personal safety when handling HCN can be stated thus:

HCN + no hood = Past Tense,
HCN + a hood = Present Tense.

LEWIS W. GLEEKMAN
Assistant Professor in
Chemical Engineering
University of Delaware

Hot Extrusion of Steel Tubes

OHIOPYLE, PA.

Many articles in American technical journals during the last couple of years have described the post-war process of cold steel extrusion, usually in connection with the manufacture of projectiles. Several of these note that the idea originated in Germany during the early years of World War II. The germ of the idea certainly antedated that time.

In Europe in 1929, I was told that Mannesmann in Dusseldorf, Germany, was experimenting with the extrusion of hot steel, and in August of 1931, I was permitted to see the extrusion plant in Witten (Ruhr). The press was either of 600 or 800 tons capacity, crank-operated. (I was told that hydraulic operation was not fast enough.) The enormously rapid deformation almost melted the steel as it passed through the die. The tubes were smooth and apparently concentric.

In 1935 I again visited the Witten works; a 4000-ton press had been added. Extrusion of 40 ft. of pipe, vertically downward, in a little more than a second was an impressive sight. Again, the product was excellent. The enormous pressure in the die caused the steel to flow; pressure on the back end of the die shortened its length from front to back. The metal in the die, being fairly tight in the die holder, had no place to go except to flow into the open hole at the center, reducing the diameter of the orifice.

On the other hand, some metal was worn away by friction. The two effects did not quite balance each other, with the result that the outside diameter of the extruded tubes

gradually became smaller! When this dimension approached the limit of tolerance, a new die was put into the press and the old one reground to shape.

The plug was, and presumably is now, water cooled. In consequence, it could not become soft enough to be deformed by pressure, but wears so that tubes, as extruded, become rough on the inside. The tubes are currently inspected for roughness, and a new plug is inserted upon a signal from the hotbed inspector. The maintenance cost of the plugs was three times as high as the maintenance cost of the dies.

In 1939, I once more visited the Witten works. One more press of 3000 tons capacity had been added. I was told that another press was in operation in central Germany and that a similar press was in operation in Japan.

Two men, Singer and Liebergeld, had approached Mannesmann and had asked for experimental facilities. They were interested in the extrusion of noncircular and odd shapes. They complained bitterly that Mannesmann would let them have the press for that purpose on Sundays only. Their attempts failed because the reduction of orifice diameter, so fortunate for circular shapes, caused very frequent and prohibitively expensive regrinding of the dies.

W. TRINKS
Professor Emeritus
Carnegie Institute of Technology

Gas-Liquid Carburizing

BRIDGEPORT, CONN.

The nature of my business has brought me inside the heat treating departments of several aircraft plants. The majority of carburizing furnaces I have seen are of the vertical retort-type with a sand seal and use fluid carburizing media. Generally, operators and technicians speak favorably for the performance of the furnaces. However, many are in favor of carburizing under pressure which eliminates occasional "subsurface" oxidation.

I tried the following experiment: In addition to carburizing fluid, a flexible hose was attached to the "T" in the dripper connection and endothermic gas from a nearby generator was piped into the furnace. The results were most gratifying; there was no subsurface oxidation, no sooting — because a smaller amount of carburizing fluid is required — and, in the event a leak develops in the retort, sand seal, or fan bearing, the positive pressure of gas prevents entry of air into the retort. In addition it was possible to cool work in the furnace under atmosphere well below 1250° F. and thereby prevent the slight scaling and loss of surface carbon that results from cooling in air.

VICTOR KAPPEL
President
Connecticut Metal Treating Co.

Lost Art of Hardening Copper

MINNEAPOLIS

A discovery has been made by C. H. Audette of this city for which he has been granted a patent. This "discovery" is an alloy composed of 70% copper – 30% high-carbon steel, believed to be the toughest metal known. It can be rolled to 1/8 in. thick and is as flexible as spring steel.

G. E. ERICKSON
President
Glacier Sand & Gravel Co.

Editor's Comment

This is part and parcel of the annual discovery of "the lost art of hardening copper" which has been trumpeted annually from the daily press for as long back as I can remember. Frequently, news of this discovery is also attached to the news that it has been sold to some multi-million-dollar steel company for not much less than a million dollars!

Lower Oxides of Titanium

VICTORIA, AUSTRALIA

During an investigation of the high temperature oxidation of titanium and its alloys, the structure and properties of the oxide scales and underlying metal solid solution have been studied. This program involved the production of standard titanium-oxygen alloys in steps of 5-atmosphere percentage oxygen up to the maximum percentage at the composition TiO_2.

Direct production of the oxides has been made possible by a procedure involving the melting of pressed and partially sintered TiO_2 bars in an arc furnace using argon atmosphere. Although TiO_2 is a nonmetal, heating

the bars in the plasma of the direct-current arc increased the ionic conductivity of the oxide to such an extent that melting finally resulted. Its melting is very rapid, taking approximately the same time as the cycle for the metal itself.

Unlike titanium metal, however, the melted oxide tends to "wet" the water-cooled copper hearth, therefore care must be taken to melt the bars so as to leave an unmelted layer in contact with the hearth during each run. The compact melted oxide can then be readily melted with an appropriate amount of titanium metal, preferably in sheet form to obtain the required oxide. A certain amount of difficulty in obtaining a structurally homogeneous product has been experienced with compositions between $TiO_{1.3}$ and $TiO_{1.8}$ due to the existence in the molten state of two conjugate immiscible liquids. However, this can be overcome by the use of small charges.

A. E. Jenkins
The Baillieu Laboratory
University of Melbourne

Titanium Sticks to Indenter

Urbana, Ill.

During the course of some work on recrystallization and grain growth of titanium metal, the diamond pyramid was used to follow the change in hardness with the progress of recrystallization. After a number of hardness determinations had been made, it was noted that the indentations were no longer clean-cut but had become rough and irregular. Examination of the diamond indenter under a microscope showed that the point contained a tightly adhering coat of titanium metal, as shown in Fig. 1. The titanium was removed by abrading the diamond point with fused silica, but additional attempts to use it only caused further building up of metal.

This note is to caution others who may need to measure the hardness of titanium that hardness numbers may be considerably in error because of metal build-up.

H. P. Leighly, Jr.
Olin Industries Fellow in Metallurgy
H. L. Walker
Head, Department of Mining and Metallurgical Engineering
University of Illinois

Fig. 1 — Point of Pyramid Indenter With Adhering Coat of Titanium Metal

Mounting Material for Specimens

Lancaster, Pa.

Visitors to our metallurgical laboratory have shown a great deal of interest in our use (since 1944) of Melmac-WB-48 Ivory as a mounting material for small metallographic specimens. This thermo-setting plastic is harder than bakelite, which is an advantage during polishing. It has a tendency to crack when used for large specimens but no difficulty has ever been experienced when mounting small specimens using a pressure of 3500 psi. and temperature of 300° F. Melmac can be obtained in different colors from the American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N. Y.

L. A. Hurwitz
Chief Metallurgist
Hamilton Watch Co.

Statement in Symposium Clarified

Detroit

I have read the published transcript of my remarks concerning the substitution of straight chromium alloys for 18-8 in castings in the September issue of *Metal Progress* and note that the editors have added a final paragraph to my text.

This added paragraph leaves the impression that most alloy foundries can produce all of these difficult types of straight chromium alloy castings with little or no trouble, which I am sure is contrary to general experience in the industry, and certainly contrary to our experience here. While some producers may make a specialty of this type of work, and do a good job, I believe that by and large the average producer would handle such types with caution.

R. J. Wilcox
Technical Director
Michigan Steel Casting Co.

By **Arthur H. Allen**, Technical Business Consultant, Cleveland

Modern Brass Mill Turns Out Quality Products in Quantity

WHILE THERE is nothing unusual about a plant "open house", the press representative who attends is not always allowed to stray away from the carefully marked routes nor is he always escorted by such competent guides as were provided by Chase Brass & Copper Co. Chase opened the doors of its two 500,000-sq.ft. plants in Euclid, Ohio, east of Cleveland, to employees' families and the general public, on September 24 through 26. Press representatives made the two-mile tour in advance of the formal opening, escorted by Ralph Ricksecker and his staff of metals engineers and product control engineers. Casting, rolling, extrusion, piercing and drawing of dozens of different copper and brass alloys were observed. The running commentary for our group was provided by Jake Vreeland, veteran Chase metallurgist, who transferred to Cleveland from Waterbury in 1948; he proved to be a veritable walking encyclopedia of brass mill technology.

The two plants, situated on a 176-acre site providing ample room for a broad range of operations and for future expansion, include the original facility on Babbitt Road built during the great depression at a cost of $8,000,000 and now devoted principally to production of rod and tube; and the plant on Upson Road built in 1941 under Government auspices at a cost of about $15,000,000 for manufacture of cartridge cases. It was purchased by the company in 1946 for $5,000,000 and re-equipped for turning out sheet and strip products.

Reportedly it is the largest mill of its kind under one roof. Monthly output of both plants figures close to 6,000,000 lb. of sheet and strip, 6,000,000 lb. of tubing and 4,000,000 lb. of rod. Standard alloys number at least 40 and there are dozens of special alloys furnished to customers' specifications. In addition to copper and standard brass alloys, silicon bronze, phosphor bronze, leaded bronze for bearings, and copper anodes are included among the many products on the company's list.

To support this production, monthly metal consumption includes 4,000,000 lb. of fire-refined copper ingots and cathodes, 3,000,000 lb. of copper cakes, 6,000,000 lb. of copper billets for piercing, 4,000,000 lb. of copper and brass scrap (mostly from customers), 2,500,000 lb. of zinc, 100,000 lb. of lead, 20,000 lb. of tin and smaller amounts of other alloying materials such as antimony, chromium and silicon. Even with this healthy intake, and close relationships with the Kennecott Copper Corp., one of the world's largest miners and refiners of copper, there is currently a shortage of copper, despite efforts to reinforce stocks with high-cost foreign metal.

A noteworthy feature is the high degree of metallurgical control which is practiced, all the way from the batteries of induction melting furnaces to shipment of finished materials. Even under ideal conditions a high percentage of "home" or circulatory scrap is generated in brass mill operations. Between melting furnace and shipping dock, scrap may run as high as 30 or 40%, not counting occasional customer rejects. The effort to keep scrap at a minimum and to classify and segregate what is generated taxes the ingenuity of control engineers. A large part of this work is educational — impressing the man on the machine with the importance of proper scrap handling and with the waste involved when careless intermixing is allowed.

Melting is carried out at the Upson Road plant in 24 induction furnaces; eight more are provided in the Babbitt Road plant. Each furnace has capacity of roughly 3500 lb. and can handle 8 to 12 heats per hr. Total power load of the two plants is more than 6,000,000 kw-hr. a month. The various heating and annealing furnaces require on an average 35,000,000 cu.ft. of natural gas a month, and 300,000 gal. of liquid propane is stored for standby purposes in winter when restrictions on gas usage may be in force.

First step in the conventional produc-

tion of copper or brass sheet and strip is to cast the alloy into cakes weighing about 2000 lb. each. These are heated to 1400 to 1600° F. in a circular hearth furnace fired from the outside rim. It furnishes 28 cakes an hour to a two-high reversing hot mill which rolls the 4½-in. cake down to 0.375 in. and elongates it from 5 ft. to 60 ft. in a matter of 90 sec. After end shearing and quenching, the bars are "scalped" at a speed of 30 ft. per min. under cutters turning at 900 rpm. About 0.015 in. is removed from each surface.

The largest of the plant's cold rolling mills — a four-high tandem type — converts the 60-ft. scalped bar into a coil of strip 220 ft. long and $\frac{3}{32}$ in. thick, in two passes at a speed of 1000 ft. per min. A 40% reduction in section is about the maximum possible on any copper alloy in conventional rolling mills without subsequent annealing. The temperature range for annealing is 1000 to 1250° F.: bell-type controlled-atmosphere furnaces as well as continuous furnaces are used. Subsequent pickling treatments consume 12,000 gal. of sulphuric acid monthly. All pickling wastes are neutralized before disposal. Incidentally, Chase Cleveland plants use a neat 400,000,000 gal. of water a month, readily available from Lake Erie.

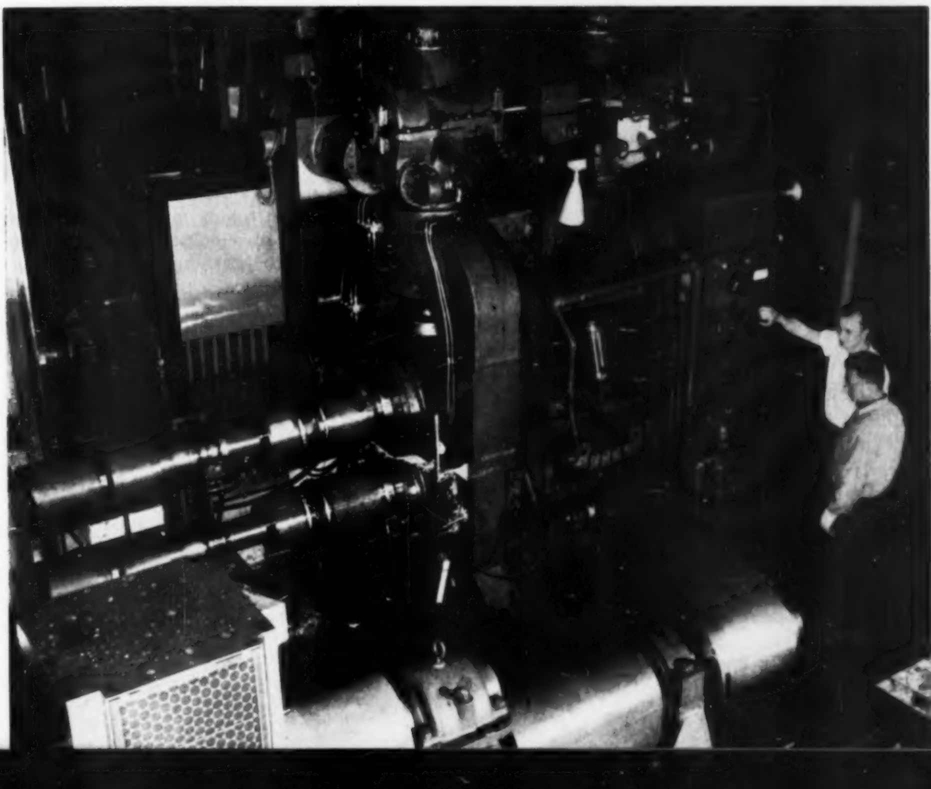
Among an assortment of finishing mills is a new two-high nonreversing unit which operates at 1000 ft. per min., handling coils from 8 to 16 in. wide and rolling to a finished thickness in the range of 0.005 to 0.040 in. (See Fig. 1.)

A four-high single-stand cold mill is used for material 25 in. wide and 0.012 to 0.040 in. thick, also at speeds up to 1000 ft. per min. An X-ray gage on this mill measures the thickness continuously and automatically regulates the roll setting.

An electrically heated vertical unit is used for continuous annealing and pickling of 25-in. strip. Coils are attached end to end as they enter the feed rolls. At first an attempt was made to spot weld the coil ends, but this was later discarded in favor of a pinning method in which matching slits are cut near the overlapping ends and a rod inserted through the openings to hold them together. (See Fig. 2, overleaf.)

One of the latest installations is a $600,000 Sendzimir or cluster-type reversing cold mill

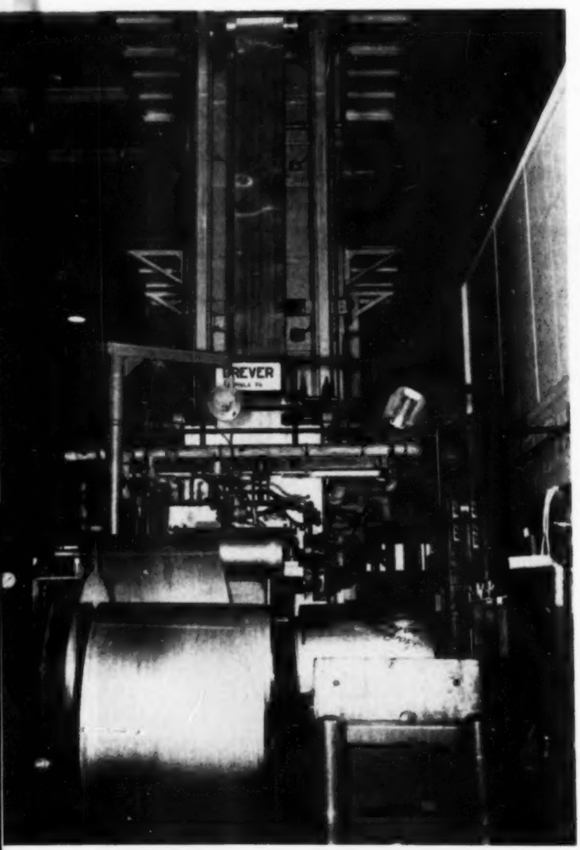
Fig. 1 — Push-Button Control Features This Bliss Two-High Cold Finishing Mill. Brass or copper strip up to 16 in. wide is rolled down to 0.040 to 0.005-in. gages at speeds up to 1000 ft. per min.



which will roll thin stock at phenomenal rates. Three 2000-lb. coils are welded end to end in an inert-gas arc welding machine and rolled from 0.075 in. down to 0.004 in. at extraordinary speed and to extreme precision, making a finished coil of strip some three miles long.

Among smaller rolling mills are two four-high nonreversing stands for finishing 7-in. radiator fin stock. They roll down to 0.004 to 0.005 in. at 1000 ft. per min. A full complement of slitting and sawing equipment is provided to cut narrow widths of strip to specified lengths.

Fig. 2 — Entrance End of Continuous Annealing and Pickling Machine. Strip is pulled through the furnace and pickler in an "endless ribbon", made by pinning each coil to the one ahead before it enters the vertical furnace



Melting operations at the adjoining Babbitt Road plant are confined to leaded brass alloys for subsequent extrusion or piercing. High-lead materials contain about 1.75% Pb, low-lead around 0.50%. Extrusion is limited to brass alloys, while piercing is largely done on copper.

A 2250-ton horizontal extrusion press starts with an 8-in. diameter billet 15¼ in. long, heated in a gas-fired furnace to 1400 to 2000° F., depending upon the alloy, and "squirts" it into a 3¼-in. tube 15 ft. long with wall thickness of perhaps ½ in. The starting billet weighs somewhat over 200 lb. and the only loss in the extrusion operation is the small plug remaining in the container between extrusion ram and exit die. As is well known, a wide assortment of shapes can be economically produced by extrusion, including many architectural specialties and building trim.

Chase is now in process of installing equipment for production of capillary tubing, with diameter on the order of 0.050 to 0.070 in.; one important use is for control instruments. Extreme precision is required in drawing this material.

Other tubing is produced in a complete range of sizes up to about 3½ in. Single, double and triple draw benches are operated, some at speeds as high as 300 ft. per min. Intermediate anneals are frequently necessary in taking tubing down to small diameters, and both gas and electric furnaces are employed. In the bright annealing of refrigerator tubing, an interesting procedure is the purging of the coil with annealing gas before it enters the furnace; the gas is blown out after the coil leaves the furnace.

As rod and tubing are drawn down in size, they naturally elongate considerably and it is necessary to determine the most economical lengths into which they shall be cut, in order that customer orders can be filled expeditiously with a minimum of scrap lengths. This is sometimes a complicated problem.

Chase Brass & Copper, now a Kennecott subsidiary, has come a long way since its modest beginnings in 1876 in Waterbury, Conn., then the brass capital of America. The countless forms of rod, bar, sheet, strip, plate, tube, pipe, extruded and drawn shapes being shipped daily from the well-fitted Cleveland plants are a tribute to the mechanical and metallurgical knowledge, skillful supervision, resourceful management and 2600 enthusiastic employees of the Chase organization.

By **Fred C. Schaefer,** Sales Manager, American Gas Furnace Co., Elizabeth, N. J. and
Richard L. Burdsall, Secretary, Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

Automatic Heat Treating Line With Duplex Quench — Either Oil or Water

PROCESSING of carbon and alloy steels in a modern plant manufacturing bolts and nuts demands a rather unusual degree of versatility to meet the changing specifications of large purchasers, not only as to sizes, shapes and uses but also as to physical properties. Heat treatment is a vital step in the mass production of such quality goods. Hence a new line-up of batch loader, continuous heat treating machine, automatic quench tanks in duplicate (side by side), and washing machine, as installed at the Port Chester plant of Russell, Burdsall & Ward Bolt and Nut Co., will be interesting to metals engineers. This plant was a large producer of carriage bolts in the horse-and-buggy days, and these same carriage bolts — now used for many purposes — are still a major product. However, the Port Chester plant makes a large variety of other types of screws, bolts and fasteners, and the main idea behind the equipment to be described, designed and installed by American Gas Furnace Co., is its adaptability, its ability to change promptly from the job of oil quenching and washing one type of bolt to water quenching another type, and its economy in comparison with the previously used batch treatment in salt pots.

The combination or double tank shown in the drawing, Fig. 1, is welded of $\frac{3}{16}$-in. steel plate and has suitable structural steel bracing and supports. It is mounted on wheels and can be moved sideways, back and forth. One of the tanks contains water, the other oil. Provision is made through hose connections for filling, draining and circulating the quenching mediums; steam coils in the oil tank maintain the temperature as specified by the work ticket.

The principal problems arising when oil and water are interchanged in one quench tank have been that the oil contaminating the water, or vice versa, ruins either quench, and that the oil foams and otherwise creates undesirable and troublesome conditions. Likewise oil and water quenches require different conditions. For example, a desirable oil quench should be held at 120° F., while water needs to be kept cool by constant replenishing and circulation. The new double tank saves the time required to empty and fill a single quench tank and avoids the troubles just noted.

The oil quench tank is a complete unit welded alongside the water quench tank. Each has its own circulatory system. Installed in the oil tank is a steam heating coil that extends approximately two thirds its length; this maintains a constant temperature of about 120° F. If heavy through-put tends to overheat the oil, it can be circulated through an external cooling system (the Niagara Aero Heat Exchanger) by a 100-gal.-per-min. pump.

Each tank has its own complete conveyer system, motor-operated and controlled from the main floor level. A four-speed variable transmission provides for variation of quenching time. The conveyer belt is of a fine cord-weave wire mesh, and can carry any product ranging from the plant's smallest up to the largest the furnace retort can handle. It is set on an extended pitch chain that rides in roller mountings on an angle iron track at either side. At each edge is a flexible guard; flights are provided on the mesh to prevent bunching on the incline.

Heated work from the rotary retort falls through a chute whose lower end is immersed in the quench. The drawing, Fig. 1, indicates the automatic seal, spring loaded, which prevents air from reaching the work as it passes from the heating machine into the quench. It is so constructed that whenever the tank is moved to one side or the other the seal is transferred also. Vapor arising in the chute from the oil is burned by an exhauster called the gas vapor eductor.

The water quench tank is the same

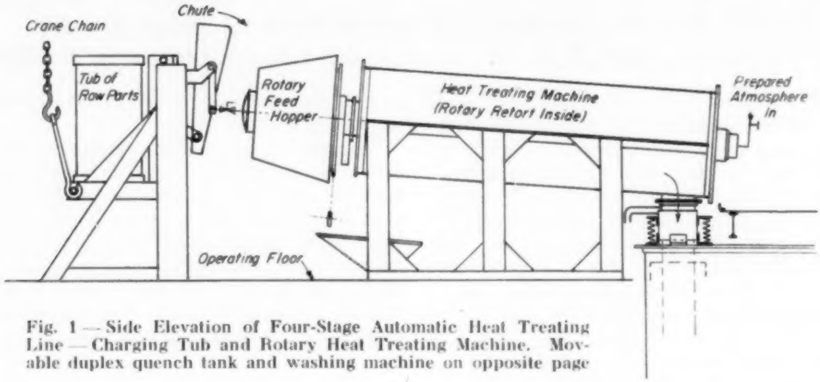


Fig. 1 — Side Elevation of Four-Stage Automatic Heat Treating Line — Charging Tub and Rotary Heat Treating Machine. Movable duplex quench tank and washing machine on opposite page

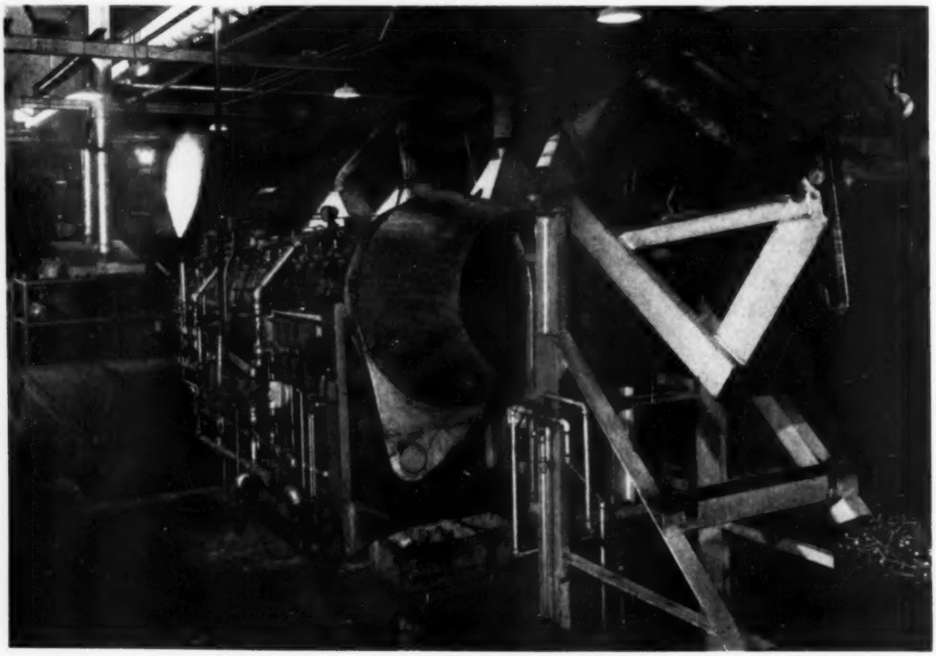
shape and size as the oil quench alongside. No heating system is required; in fact, the water is kept cool by a solenoid-operated system which brings in the necessary amount of make-up water. The discharge line takes care of the overflow, and a steam exhauster leads from the spring-loaded seal above the entrance chute.

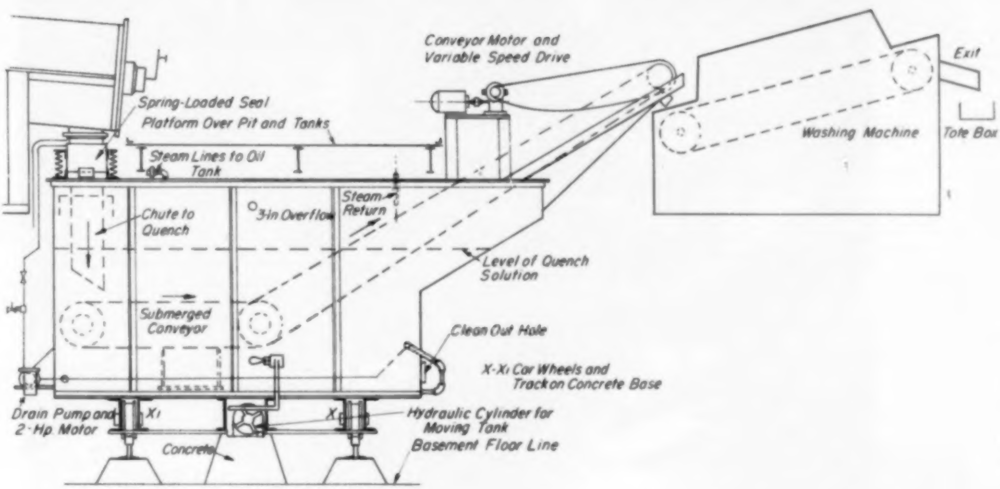
Both tanks are provided with manholes and connections for draining. They may also be entered through a trap in the platform over the pit.

OPERATIONAL AND SAFETY FEATURES

This double tank is mounted on car wheels and railroad rails for sidewise movement in a pit of ample size. Actual shuttling is simply done by hydraulic cylinder operat-

Fig. 2 — Line-Up From Charging End





ing from the plant's 120-lb. water supply. Although the Russell, Burdsall & Ward Co.'s plant has the usual fire protection system, an added safety system is installed on the tanks and conveyers known as a Grinnell Protecto Spray System to cover all points of the quench tank where danger could possibly develop, as well as a spray system to envelop the conveyers completely.

The advantages of the combined oil and water quench tank cannot be fully appreciated until the entire line-up has been described. The four automatic stages are:

1. Loading the material into the hopper.
2. Heating the material in the American Gas Furnace Co.'s heating machine.
3. Quenching the material (in oil or water as the needs require).
4. Cleaning or degreasing.

At the time the photographs were taken, this four-stage system was producing 670 lb. per hr. of shackle bolts. After passing through the heat treating and cleaning equipment they dropped into tote pans and then were dumped directly into cartons for shipment. Heat treating is done in a controlled atmosphere containing ammonia, and the result is a clean "Ni-Carbing" job. It is expected that the hourly production will shortly be increased to exceed 1000 lb. per hr., but production will vary of course with the heating cycle, the quenching time, and the nature of the product being heat treated.

A new type of loader is indicated in the drawing and was provided by the R. B. & W. Co. An overhead crane places tubs of bolts, nuts or screws on the cradle and tilts each tub so the work falls into the rotary hopper (a part of the heating machine) of sufficient size to contain a half-hour's supply. The hot retort itself is fed from this hopper by an internal scoop — a little at each rotation. The load in the furnace is thus determined by the speed of rotation and the adjustment of the hopper.

The rotating retort of the American Gas Furnace Co.'s heating machine has an internal spiral which conveys the work uniformly from end to end, while excluding furnace gases and other unwanted vapors. This permits the work to be surrounded with any desirable atmosphere, depending upon the treatment wanted. As noted, an atmosphere containing nitrogen, which gives a superficial nitriding action, is much desired for an important portion of the factory's output. The discharge is through the spring-loaded seal already mentioned, thus protecting the work at all times from oxidation. Heating time is controlled by the variable-speed drive that operates the retort.

The rotating retort type of furnace is preferable for bolts, nuts and screws because it permits heating the work rapidly and it insures uniform heating. The work is well distributed. The constant rotation of the retort against the air-gas flames from several burners insures uniformity of heating.

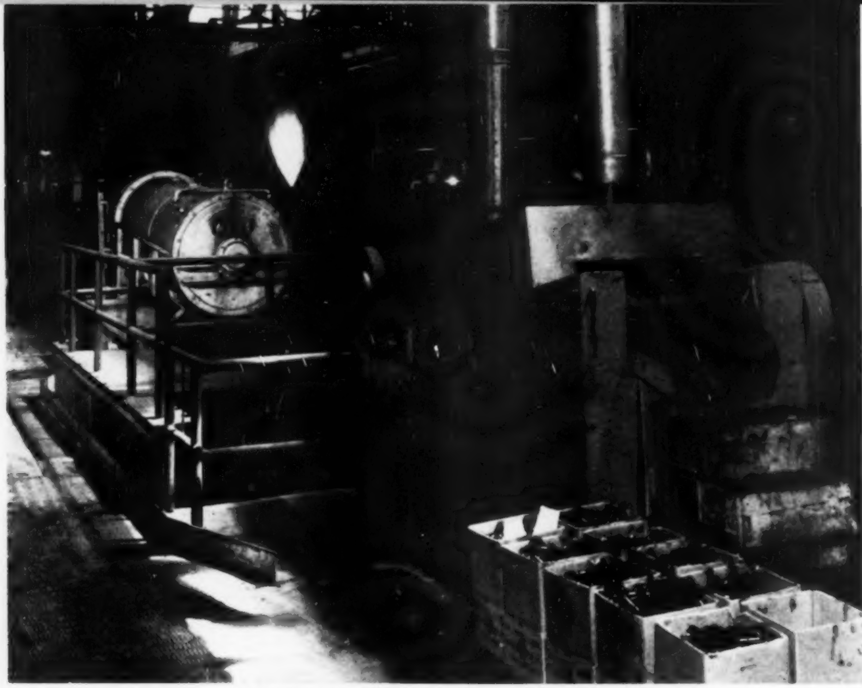


Fig. 3 — Line-Up From Discharge of Washer

Furnace temperature is controlled by a Leeds and Northrup indicating potentiometer operated on "high" and "low" (not "on" and "off"). At the discharge end is a Leeds and Northrup strip-chart recording controller with automatic reset.

Emerging from the quench, the work falls into a Ransohoff Belt-Type Washing Machine. When the water quench tank is used, then the washing machine simply becomes a drier.

Since this installation has not yet operated long enough for accurate performance figures, representative operating costs of similar installations are taken from the records of American Gas Furnace Co. Purchase, maintenance and operational costs are as shown at the top of the next column.

Based upon a minimum hourly production of 750 lb., the estimated cost of treating shackle bolts amounts to \$0.0045 per lb. — less than ½¢ — exclusive of the slight additional cost of the washing machine, its maintenance and operation.

CONCLUSION

Another model of heating machine of the same type made by the American Gas Furnace Co., has been in use in Russell, Burdsall & Ward Bolt and Nut Co.'s Port

Depreciation over 10 years on value of equipment less retort (\$20,000 divided by 10 or \$2000 per year, or \$8.00 per day, or 40¢ per hr. for a 20-hr. day.)	\$0.40 per hr.
Retort replacement; \$2500 divided by 5000-hr. life	0.50
Furnace heating gas; 750 cu.ft. per hr. natural gas at 15¢ per 100	1.12
Atmosphere gas, 100 cu.ft. per hr. of natural gas	0.15
Ammonia, 35 cu.ft. per hr.	0.24
Electric energy for motor, blowers and pumps	0.05
General maintenance, including thermocouples, lubrication and bearings	0.02
Labor, ½ hr. at \$1.80 per hr.	0.90
OPERATIVE COST	\$3.38 per hr.

Chester plant since 1946. Both furnaces and this new quench arrangement have proven so successful that another double quench tank is now being installed.

Although heat treating by the salt bath method is still being done for some established purposes, this new installation has provided a safe and clean means of accomplishing an improved result. The workmen like it because it frees several men from rather unpleasant work. The company likes it because it provides better working conditions and improves production as well.

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How SILICOMANGANESE Saves Furnace Time . . . Produces Better, Cleaner Steel

Silicomanganese is used by the steel industry as a furnace block* and deoxidizer, and also for manganese additions.

The cleanness and quality of steel depend largely on how well it has been deoxidized. Deoxidation also greatly influences the physical properties of steel for rolling and subsequent fabrication. Silicomanganese combines two active deoxidizers in a single alloy and it has proved to be a more effective deoxidizer than silicon or manganese alloys added separately. This combination alloy contains silicon and manganese in the correct proportion (approximately 1 to 3.5) to be most effective in reducing the oxygen content of the bath to a low level. The use of silicomanganese produces cleaner steel, saves furnace time, and gives high alloy recovery for manganese additions.

Gets More Oxygen Out of Bath

When silicomanganese is used for blocking and deoxidation, the combined effect of silicon and manganese lowers the oxygen content to a greater degree than silicon alone. This is due to the fact that the amount of oxygen in equilibrium with a given amount of silicon is lower in iron-silicon-manganese alloys than it is in plain iron-silicon alloys, as shown in Fig. 1.

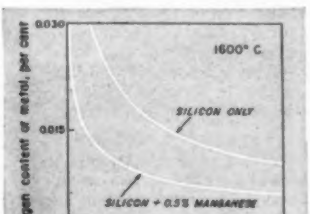


Fig. 1. Limit of solubility of oxygen in iron-silicon alloys, plain and with 0.50 per cent manganese at 1600°C.

*The initial deoxidation of steel, frequently referred to as the furnace block, stops the carbon-oxygen reaction in the furnace. This arrests the carbon drop immediately and makes it possible to secure close control of analysis. If the oxygen content of the metal is reduced well below the level established by the carbon-oxygen reaction, initial deoxidation is accomplished.

Less Inclusions, Cleaner Steel

In addition to lowering the oxygen content, silicomanganese has a specifically beneficial effect on inclusions. The inclusions in a steel depend in large part on how low the carbon content (or how high the oxygen content) is before blocking. The lower the carbon, the dirtier the final steel, almost regardless of the subsequent deoxidation treatment. Since silicomanganese has a low carbon content, it is not necessary to drive the carbon as low (or make the oxygen as high), as when high-carbon or standard ferromanganese is used, so that the final steel is cleaner and has better working properties. The improved cleanliness resulting from silicomanganese is usually noticeable in higher carbon steels, but is outstanding in steels below 0.25 per cent carbon where inclusions and surface defects are a vital problem and where the time saved by blocking at a higher carbon level is significant.

Fast Solubility In Bath

Because of the high concentration of active elements in silicomanganese, less time is required to effect solution of this alloy than when equivalent amounts of silicon and manganese are used separately in the form of ferrosilicon and ferromanganese.

For example, compare these typical analyses of silicomanganese, standard ferromanganese, and 50 per cent ferrosilicon:

	Silicomanganese, %	Standard Ferromanganese, %	50% Ferrosilicon, %
Manganese	66.5	80	—
Silicon	19	—	50
Carbon	1.5	7	—
Iron, approx.	13	13	50

From this it can be seen that 1,000 lb. of silicomanganese would contain 190 lb. of silicon and 665 lb. of manganese. These amounts of silicon and manganese would require 380 lb. of 50 per cent ferrosilicon and 830 lb. of standard ferromanganese, or a total of 1,210 lb. Obviously it is easier and faster to dissolve 1,000 lb. of the combination alloy silicomanganese than 1,210 lb. of these separate silicon and manganese alloys.

Lower Carbon Content

Silicomanganese contains less carbon than any combination of ferrosilicon and standard ferromanganese. Therefore, the carbon-oxygen reaction in the bath can be stopped earlier when silicomanganese is used for blocking. Heats can be blocked at higher carbon levels and hence lower oxygen contents, and the amount of deoxidation required is less.

Fig. 2. Charging silicomanganese into an open-hearth furnace.

Saves Furnace Time

Because of the advantages outlined, silicomanganese can save as much as 20 minutes per melt in the production of open-hearth steel. For low-carbon steel, an even greater saving in time can be realized.

For Producing Engineering Steels

Silicomanganese is also used for alloy additions of manganese, particularly in the production of engineering steels containing 0.10 to 0.50 per cent carbon.

When manganese or other oxidizable additions, such as chromium, must be made to the bath, the use of a block provides a higher alloy recovery. Silicomanganese introduces manganese with the silicon and the usual recovery of this manganese will range from 70 to 85 per cent.

Metallurgical Service Available

Ask to have one of our metallurgists call and explain more fully the advantages of silicomanganese as a furnace block and deoxidizer. He will be glad to help you with the use of ELECTROMET silicomanganese. This alloy contains 65 to 68 per cent manganese and is produced in maximum 1.50, 2.00, and 3.00 per cent carbon grades. All grades are furnished in a lump size of 75 lb. x 2 in. and in a crushed size of 2 in. x down. Write, wire, or phone the nearest ELECTROMET office.

Personal Mention

Wayne H. Keller

C. H. Desch

WAYNE H. KELLER has been appointed director of the chemistry department at National Research Corp., Cambridge, Mass., with responsibility of a large research program aimed at the economical reduction of metallic titanium. Dr. Keller, a native of Kentucky, did his undergraduate work at Georgetown College, Georgetown, Ky., and his graduate work at the University of Kentucky and Cornell University. He received his Ph.D. in physical chemistry from Cornell in 1937. During the years between 1927 and 1942 he was on the faculty of the chemistry departments at the University of Kentucky and Morehead State Teachers College, Kentucky. Dr. Keller joined the uranium project at Iowa State College, Ames, Iowa, in 1942, where he was director of chemical metallurgy for the Manhattan District program. He was one of the co-developers of the process by which uranium is made and also contributed to the development of other metals necessary to atomic energy projects. In 1945 he joined the staff of the Mallinckrodt Chemical Works, St. Louis, as assistant technical director on the uranium project. Dr. Keller's publications include contributions to the fields of colloidal chemistry, the energy states of crystalline solids at low temperatures, the production of rare earth metals, as well as numerous reports on uranium.

C. H. DESCH has been elected an Honorary Member of the American Society for Metals. An Honorary Member is one determined by the Board of Trustees to have made exceptional contributions to the field of metallurgy. Dr. Desch joins Benjamin F. Fairless, Axel Hultgren, Zay Jeffries, Charles F. Kettering, Kotaro Honda and Willis R. Whitney. He was born in 1874 and educated at University College, London, and Wurzburg University. In 1902 he entered the metallurgical department of King's College, London, and then became lecturer in metallurgical chemistry at Glasgow University until the end of World War I. For the next two years he was professor of metallurgy at Royal Technical College, Glasgow, and was appointed to the chair of metallurgy at Sheffield University in 1920. From 1932 to 1939 Dr. Desch was superintendent of the metallurgy division of the National Physical Laboratory. On his retirement he was appointed to the board of directors of Messrs. Richard Thomas and Co., Ltd., to direct research and development activities. Later he was associated with Whitehead Iron and Steel Co., Ltd., as technical advisor. Dr. Desch was elected a fellow of the Royal Society in 1923 and was president of the Faraday Society from 1926-28, president of the Institute of Metals from 1938-40, and president of the Iron and Steel Institute from 1946-48. His awards include an honorary degree of doctor of law, the Bessemer Gold Medal of the Iron and Steel Institute in 1938, and the Platinum Medal of the Institute of Metals in 1941. Dr. Desch is the author of many books, among which are *Metallography*, *Intermetallic Compounds*, and *Chemistry of Solids*.

S. Frederick Magis, consulting engineer with 26 years experience in the steel industry, has been named steel technologist at Armour Research Foundation of Illinois Institute of Technology. Mr. Magis has been assigned to one of three Point IV industrial projects the Foundation's International Division is conducting in Pakistan. With headquarters in Karachi, he will survey Pakistan's steel plant operations, lend technical assistance to speed up production, consider use of natural resources in the industry, and train plant personnel.

Walter Edens has joined the staff of scientists at Allis-Chalmers Mfg. Co., Milwaukee, as supervisor of melting and foundry research. He was associated successively with Heil Co., Ampco Metal, Inc., Badger Brass & Aluminum Foundry Co., and Alloy Engineering & Casting Co., in the past 15 years. A past president of the Milwaukee Chapter, he is also author of the bronze centrifugal casting section of the *Metals Handbook*.

William J. Thomas, general sales manager of Tubular Products Div., Babcock & Wilcox Co., has been named to the board of directors of the division. A graduate of Carnegie Institute of Technology, he has been associated with Babcock & Wilcox since 1932 and has been with the Tubular Products Div. since 1941.

Joseph C. Danec, formerly in the research and development department at Norton Co., Worcester, Mass., has been made assistant to the production engineer of Norton Behr-Manning Overseas, Inc. Prior to this appointment he was in charge of laboratory research and development of metal bonded diamond products.

Arthur E. Chambers, who was formerly with Morse Chain Co., Ithaca, N. Y., as assistant master mechanic, is now sales engineer for Eglinton Carbide Products, Inc., Detroit.

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Personals

M. J. Day ⊕, formerly assistant metallurgical engineer for alloy steels at U. S. Steel Co., Pittsburgh, has joined Armour Research Foundation, Illinois Institute of Technology, as manager, materials and processes division.

John H. Treichler ⊕ has resigned his position of sales engineer with Beryllium Corp. to join Kingston (N. J.) Trap Rock Co.

Anton deS. Brasunas ⊕ is now on the staff of the department of chemical engineering, metallurgy division, University of Tennessee, Knoxville. He was previously a metallurgist at Oak Ridge National Laboratory.

Eugene V. Ivanso ⊕ has been named head of metallurgical engineering and research at Detroit Testing Laboratory. He has been a metallurgical engineer for 16 years, having been affiliated successively with Bundy Tubing Co., Wyandotte Chemicals Corp. and Steel Sales Corp.

Walter L. Keene ⊕, director of research and metallurgy at Superior Steel Corp., Carnegie, Pa., is on loan to the National Production Authority, Washington, D. C., as a consultant in the iron and steel division, metallurgical and conservation branch.

The Hevi Duty Electric Co., Milwaukee, has made the following staff changes in its district offices: **Robert A. Foley** ⊕ has been transferred from the eastern district office in Jersey City, N. J., to the Chicago office. **Robert M. Palmer** ⊕ has replaced him as manager of the eastern district. **George M. Brown** ⊕ has been appointed manager of the Cleveland district and **Robert L. King** ⊕ is now sales engineer in Cleveland. **Elton E. Staples** ⊕, vice-president in charge of sales, has moved his headquarters from Cleveland to the company's main offices in Milwaukee.

John W. Queen ⊕ has been appointed manager of the Cleveland plant of Joseph T. Ryerson & Son, Inc. He was formerly manager of the alloy steel division with responsibility for alloy steel sales at all Ryerson plants. Before joining Ryerson in 1933, Mr. Queen was chief inspector and assistant metallurgist at Crucible Steel Co., Harrison, N. J.

Harold K. Ames ⊕ has been promoted to industrial engineering representative of Suburban Propane Gas Corp., covering the New England districts. Mr. Ames has been with Surburban for over ten years and during the past two years has been on the industrial staff at the home office in Whippany, N. J.

Grant S. Shoop ⊕, formerly inspection engineer in the department of metallurgy, inspection and research, U. S. Steel Co., Birmingham, Ala., is now chief inspector at the Birmingham shell plant of Englander Co., Inc.

John Alico ⊕ has joined Lake Erie Engineering Corp., Buffalo, N. Y., as project engineer specializing in forging and extrusion press applications. He has worked as a consulting engineer in the light metals field, serving various branches of the government on technical assignments, as well as industrial organizations. Most recently he was project engineer for two plants which are installing large forging and extrusion equipment under the Air Force "Heavy Press" program.

Personals

Rolland H. Reneau ⊕, upon receiving his M.S. degree in metallurgical engineering from Purdue University, has returned to France and plans to enter the Army. He will continue his ⊕ membership in the International Chapter.

George M. Thomas ⊕ is now employed by Sylvania Electric Products Inc., Bayside, N. Y., as a senior engineer.

Michael F. Wiedl, Jr., ⊕ has joined the staff of the advertising department of Atlantic Steel Co., Atlanta, Ga. For several years he headed the Southern Machinery and Metals Exposition, and is well known for his work in the development of trade shows and promotional campaigns. Mr. Weidl is secretary of the Georgia Chapter ⊕.

William P. Cooney ⊕ has been appointed sales representative in the Philadelphia district by A. Milne & Co., tool steel specialists in Philadelphia.

T. H. Wickenden ⊕, vice-president in charge of development and research at International Nickel Co., Inc., has been elected a member of the Welding Research Council of the Engineering Foundation for a three-year term beginning October 1.

William H. Miller ⊕ has been appointed chief metallurgist at Bowser Technical Refrigeration Div., Bowser, Inc., Terryville, Conn. He will conduct intensive research into the cold treatment of metals and its practical application to metal working and metal treating industries.

Ernest F. Nippes ⊕, **Warren F. Savage** ⊕ and **John J. McCarthy** ⊕, associate professor, assistant professor, and instructor, respectively, in the metallurgical engineering department of Rensselaer Polytechnic Institute, Troy, N. Y., collaborated to win the first prize of $300 in a national welding contest sponsored by the Resistance Welding Manufacturers Association. Their paper was entitled "Temperature Distribution During Flash Welding of Steel". Dr. Nippes, who is the supervisor of welding research at the Institute, also shared second prize of $200 for a paper on "Projection Welding of Steel in Heavy Gauges and in Dissimilar Thickness", written jointly with **John M. Gerken** ⊕, research associate at Rensselaer.

Wallace F. Ardussi ⊕, president of Variety Machine & Stamping Co., Cleveland, was elected president of the Pressed Metal Institute at the annual meeting recently. **K. A. Honroth** ⊕, of Freeway Washer & Stamping Co., Cleveland, and **Raymond Peterson** ⊕, Peterson Engineering Co., Toledo, were elected directors.

H. Edward Flanders ⊕ of the University of Utah was the winner of the second prize of $300 awarded by Eutectic Welding Alloys Corp., New York City, for a paper on "Welding Engineering & Theory". This was part of a $2000 International Prize Competition conducted by Eutectic.

Jason Saunderson of the Dow Chemical research department, Midland, Mich., has been appointed director of engineering at Baird Associates, Inc., Cambridge, Mass. Dr. Saunderson has been at Dow Chemical since 1939 in various research capacities in the field of physical and chemical measurements, and pioneered in the field of spectrometry.

Personals

Ernest S. Kopecki ⊕ has joined the public relations department of Carborundum Co., Niagara Falls, N. Y., as assistant to the manager, particularly responsible for the conduct of editorial relations with the industrial trade press. A former metallurgical editor on *Iron Age*, he has most recently been associated with Pennsylvania Salt Mfg. Co., Philadelphia, as assistant manager of public relations.

Howard M. Stein ⊕ has been promoted from director of personnel to director of advertising and sales promotion of Seaporcel Metals, Inc., Long Island City, N. Y. He formerly served as director of industrial relations for Milton Hood Ward Associates.

William M. Mueller ⊕ has accepted a position with the Dow Chemical Co. at the Rocky Flats plant near Boulder, Colo. He received a doctor of science degree from the Colorado School of Mines last May.

Henry J. Fishbeck ⊕ has been appointed staff metallurgist in the advanced tool engineering group at Pratt & Whitney Aircraft, East Hartford, Conn. For the past ten years he has been supervisor of metallurgical and chemical processing in P&WA's production engineering department. His successor is **Spencer W. Deming** ⊕, assistant supervisor since 1945. Mr. Fishbeck joined P&WA in 1929 as chief metallurgist and organized the metallurgical and heat treating departments. He was named process engineer in 1940 and supervisor of metallurgical and chemical processing in 1942. Mr. Denning has been with P&WA since 1940, coming from the U. S. Dept. of Agriculture and the Connecticut Agricultural Experiment Station.

John S. Winston ⊕ has been appointed to the staff of the Mackay School of Mines, University of Nevada, as professor of metallurgy and chairman of the department of metallurgy. He replaces Walter S. Palmer, who has retired. Professor Winston, a graduate of Cornell College, Iowa, and the Missouri School of Mines and Metallurgy, has taught metallurgy in many institutions, including Illinois Institute of Technology, the University of Chicago, the Biarritz American University, Valparaiso University, Morningside College, the Missouri School of Mines, and has also been with the U. S. Bureau of Mines, Rolla, Missouri. He is a specialist in physical properties of metals and the production and use of special metals for exacting engineering purposes.

Robert D. Reiswig ⊕ has resigned his position as research engineer with Battelle Memorial Institute, Columbus, Ohio, to accept a research fellowship at the University of Wisconsin.

Howard K. Schmuck, Jr., ⊕, formerly sales engineer, Haynes Stellite Co., Houston, Texas, is now with Colorado Fuel and Iron Corp. as product engineer, mining supply sales, located in Denver.

Curtis L. Graversen ⊕ has resigned as metallurgist with the Division of Industrial Research, Pullman, Wash., to accept a similar position with Oregon Saw Chain Corp., Portland, Ore.

John W. Fissel ⊕ has been promoted from plant metallurgist, Vandergrift plant of Irvin Works, U. S. Steel Co., to chief metallurgist and inspector, Irvin Works, Dravosburg, Pa.

Personals

William E. Cooper is now engineer, engineering analysis subunit, Knolls Atomic Power Lab., General Electric Co., Schenectady, N. Y. He was formerly on the faculty of the engineering mechanics department at Purdue University.

Charles M. Miller, formerly with Ladish Co., Cudahy, Wis., is with Westinghouse Electric Corp., Atomic Power Div., Pittsburgh.

Luther P. Begley resigned his position in the metallurgical engineering department of General Motors Truck & Coach Div., where he served 10 years, to become Western Michigan representative for D. A. Stuart Oil Co., Chicago.

K. U. Wirtz has been elected vice-president of Electric Furnace Co.'s new Canadian subsidiary to be known as Canefco Ltd. with offices in Toronto. Mr. Wirtz is also president of the parent company in Salem, Ohio, with which he has been associated for over 25 years.

W. Trinks, well known for his forty years of service as professor of mechanical engineering at Carnegie Institute of Technology and his writings on rolling mill machinery, and now retired, writes as follows:

"I spend one or two days each week in my Pittsburgh office. The greater part of the time I spend in my mountain home, 2200 ft. up, near Ohiopyle, 60 miles southeast of Pittsburgh. Here I revise my books, work in the garden and orchard, and shovel four feet of snow in the winter. I hope that at the age of 78 you will be as happy and carefree as I am now."

Norman Dirks, since 1947 chief metallurgist at Perfection Tool & Metal Treating Co., Chicago, has joined Modern Steel Treating Co., Chicago, as technical director. He is also in charge of all manufacturing operations plus developments and laboratory research.

Elvin P. Carney, chief control chemist of Metals Disintegrating Co., Elizabeth, N. J., recently celebrated his twenty-five years of service with the company. A dinner was held in his honor, attended by over fifty of his associates and the executives of the company, at which he was presented a gold watch, suitably inscribed. Prior to joining Metals Disintegrating, he was a chemist for a number of years with the National Lead Co.

Charles T. Evans, Jr., has resigned his position as director of development and metallurgy with Elliott Co., Jeannette, Pa.

H. J. Pessl, formerly chief metallurgist at Lake Erie Engineering Corp., Buffalo, N. Y., has accepted the position of assistant works manager, Gibson Refrigerator Co., Greenville, Mich.

Russell A. Bain has accepted employment at Harvey Aluminum Co., Torrance, Calif., as metallurgist in charge of the heavy press forge shop.

Jack E. Bolt is on active duty in the Navy as assistant officer in charge, welding and castings code, Bureau of Ships, Navy Dept., Washington, D. C. Lt. Bolt was formerly melting and annealing supervisor at American Brake Shoe Co., Houston, Texas, and later assistant metallurgist for the same company in Mahwah, N. J. He taught foundry courses at the University of Alabama in 1951-52 and received his M.S. degree in metallurgical engineering this year.

In Selecting Spring Steel

It's the Size of Section that Governs the Analysis

The size of a spring section is the factor that often determines the grade of steel for a given spring application.

It is considered sound practice to use a grade whose alloy content is consistent with the thickness of the finished section. A steel of medium or low alloy content will generally be adequate for use in a thin spring section. Heavier springs, on the other hand, take steels of richer alloy content to quench out properly.

Although this principle may sound simple, it calls for a careful study of spring sizes, stresses, forming methods, and heat-treatment. In this connection we will be glad to help. Our metallurgists will give you unbiased advice based on their familiarity with all grades of spring steels.

When you are in the market for alloy steels, remember that Bethlehem manufactures all AISI grades as well as special steels.

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	8650
	9260
	TS 8650
Heavy Spring Sections	9262
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Personals

John E. Angle Ⓢ has been appointed general superintendent of the Gary Sheet and Tin Mill of U. S. Steel Co. He will succeed Charles A. Ferguson who has retired after almost 40 years service with U. S. Steel. Mr. Angle is a graduate of Lehigh University with a B.S. degree in metallurgical engineering. His first job was junior metallurgist at the mill he is now heading. He advanced through various supervisory capacities — turn foreman in the sheet mill, cold reduction department, chief metallurgist and then division superintendent in the sheet mill — and in 1944 was appointed assistant general superintendent of the plant, a job he held until his promotion to his present position.

Walter B. Farnsworth Ⓢ has been appointed to the newly created position of director of research at the Monessen plant of Pittsburgh Steel Co. His former job of chief metallurgist will be filled by **Charles L. Labeka** Ⓢ, promoted from plant metallurgist. Mr. Farnsworth, a graduate of Carnegie Institute of Technology, joined Pittsburgh Steel in 1921 as a metallurgist and expediter in the metallurgical department. In 1933 he was promoted to plant metallurgist at Allenport, Pa., and in 1935 was made chief metallurgist at both plants, a position he held until his recent appointment.

Mr. Labeka is a Pennsylvania State College graduate who earned his master's degree at the University of Arizona. He came to Pittsburgh Steel in 1935 as a metallurgist in the steel division and six years later was promoted to plant metallurgist.

George M. Sinclair Ⓢ, formerly with the University of Illinois, has joined the staff of the metallurgical and ceramic department, Westinghouse Research Labs., E. Pittsburgh.

Richard L. Werner Ⓢ, recently graduated from Rensselaer Polytechnic Institute, is employed as mechanical engineer by R. D. Werner Co., Inc., Greenville, Pa.

Thomas C. Little Ⓢ, formerly from the University of Kentucky, has recently been appointed to the staff of the Y-12 plant, an atomic energy installation operated by Carbide & Carbon Chemicals Co., a division of Union Carbide & Carbon Corp., at Oak Ridge, Tenn.

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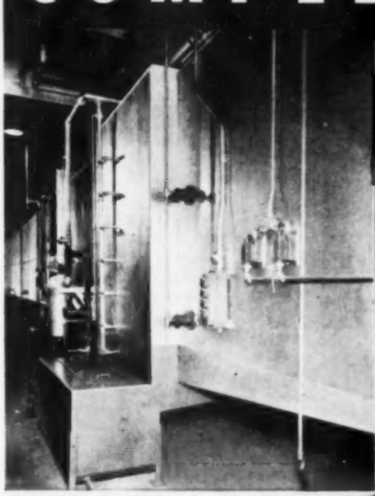
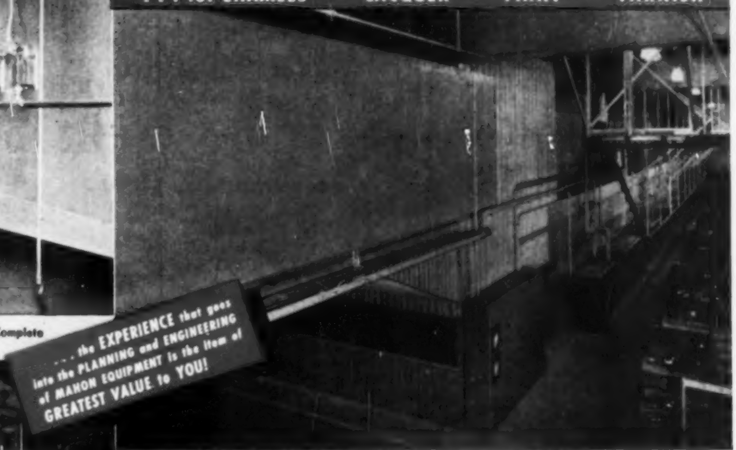
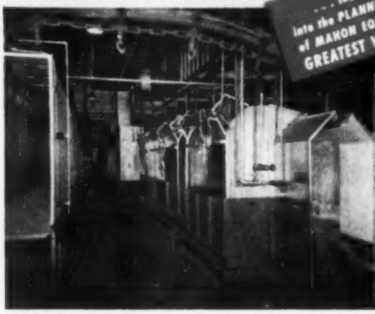


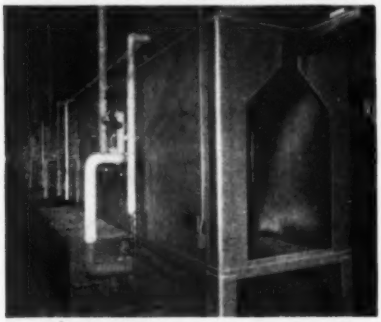
Mahon Flow Coating Machine—Part of the Complete Mahon Finishing System at Cutler-Hammer.



High Angle View of the Complete Mahon Finishing System Installed at the Cutler-Hammer Plant, Milwaukee, Wis. Note Overhead Drying and Baking Ovens, and Enclosed Paint Room Below.



Mahon Hydro-Filter Spray Booths, and at left, Drip Tunnel of Flow Coater—Parts of the complete system at Cutler-Hammer.



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Mechanism of Tempering*

THE FIRST STAGE of tempering involves the decomposition of martensite into a low-carbon solid solution and a carbide other than cementite. The second stage of tempering overlaps the first and is the transformation of the retained austenite. The third stage of tempering, involving the formation of cementite, was found to begin before the completion of the first stage. There is considerable uncertainty concerning the nature of the decomposition products produced during the first stage and the mechanism of their formation. The present paper describes a quantitative study of this question using X-ray diffraction techniques and precision measurements of length.

*Digest of "The Mechanism and Kinetics of the First Stage of Tempering", by C. S. Roberts, B. L. Averbach and Morris Cohen, © 1952 Preprint No. 11.

Seven iron-carbon alloys of high purity and two commercial carbon steels were used. These were austenitized to give complete solution of carbides and were quenched in either water or 10% brine. The amount of retained austenite was determined quantitatively, both before and after refrigeration in liquid nitrogen. For the single-crystal X-ray work, grains about ⅛ in. in diameter were produced by heating specimens for 24 hr. about 100° F. below the solidus.

Crystallographic changes in the martensitic solid solution during the first stage of tempering were observed using the single-crystal X-ray diffraction method. A single grain was oriented in the goniometer camera so that an austenite cube axis was coincident with the axis of rotation and perpendicular to the X-ray beam. The (200) (020) and the (002) components were recorded on separate films. The data obtained confirmed the first-stage mechanism reported by Kurdjumov and Lyssak — that is, the decomposition proceeded by the formation of a 0.25% carbon martensite at the expense of the primary martensite. The ε-carbide is also formed at the same time, but its diffraction lines were too weak to appear in the patterns. The carbon content of the low-carbon martensite did not vary materially with the carbon content of the primary martensite. The low-carbon martensite may be in metastable equilibrium with the ε-carbide, as both form simultaneously out of the primary martensite.

The kinetics of the first and second stages of tempering were observed by measurements of unit length changes after tempering treatments up to 5000 hr. at temperatures in the range 68 to 500° F. The effect of retained austenite was taken into account by making measurements on two sets of specimens with different, known quantities of retained austenite. The data are represented by a rate equation:

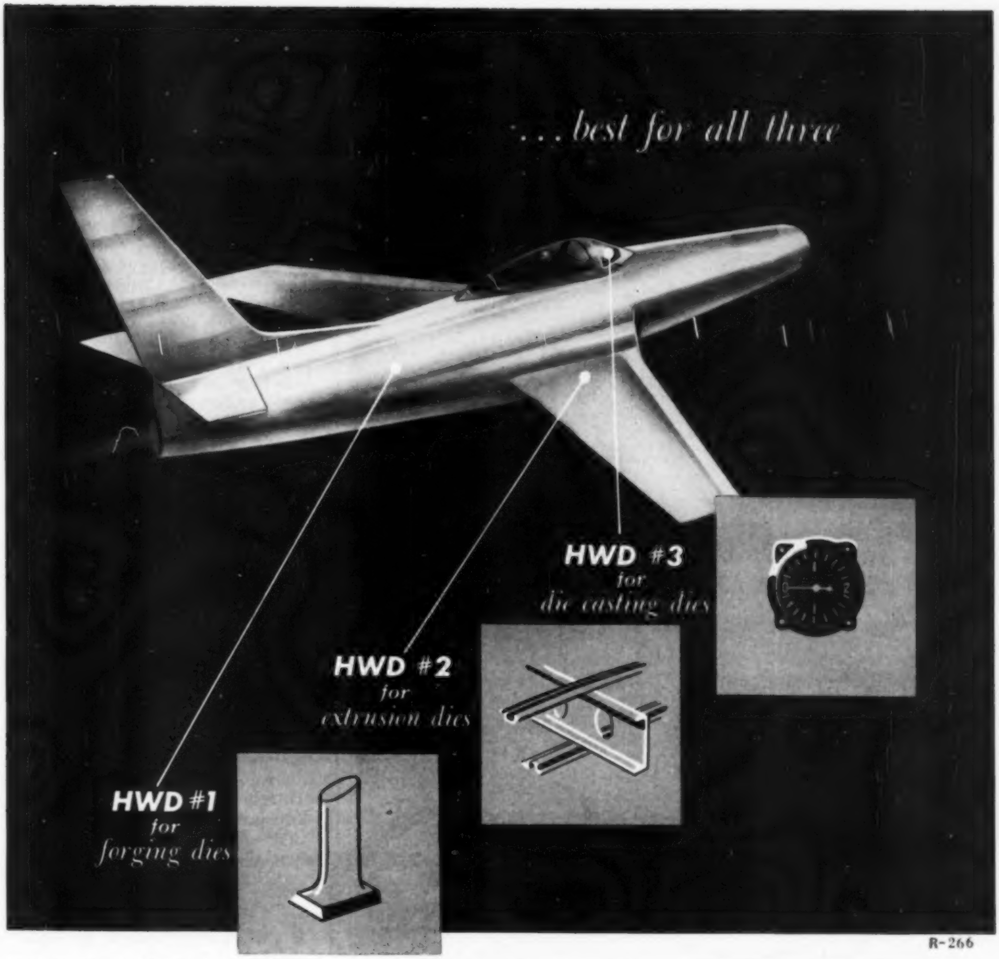
$$\frac{df}{dt} = K(1-f)t^m$$

where f is fraction transformed, t is time, K is the temperature-dependent rate constant, and m is another constant.

If y is the observed unit length change and a the total unit length change at the end of the first stage, the above equation can be integrated to the form:

$$\log\log\left(\frac{a}{a-y}\right) = (m+1)\log t + \log\left(\frac{K}{2.3}\right)$$

(Continued on p. 132)



R-266

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Mechanism of Tempering

(Continued from p. 130)

From X-ray data the value of a was computed to be:

$$a = 2930 \times 10^{-6} (C_p - 0.25)$$

where C_p is the carbon content of the primary martensite. Values of m and K were obtained from suitable plots. The value of m was found to be −0.7 and was independent of temperature and carbon content. The rate constant, K, increased with temperature, carbon content, and steel impurities.

A model of the first-stage reaction that accounts for the low value found for m is the following: The low-carbon martensite advances into the primary martensite on a plane front, with the ε-carbide precipitating or growing behind the front, and carbon diffusion being required from progressively greater distances ahead of the front as the reaction proceeds. Two predictions follow from this model: The activation energy of K should be one-half that of carbon diffusion in martensite, and K should be a linear function of the carbon content of the primary martensite. The experimental data are in good agreement with these predictions.

An argument is developed to indicate that the transformation of retained austenite to bainite during the second stage of tempering is controlled by the rate of carbon diffusion in austenite. The chemical composition of the ε-carbide has been calculated to be $Fe_{2.4}C$.

A. G. Guy

High-Temperature Alloys*

Employing X-ray diffraction studies of insoluble residues obtained by electrolytic separation, the authors have investigated the nature of the intermetallic compounds present in four heat-resistant alloys. Alloy M252 (0.15% C, 19% Cr, 10% Co, 10% Mo, 2.25% Ti, 0.75% Al, 3% Fe, 0.03% N, balance Ni); Alloy 16-25-6 (0.10% C, 16% Cr, 25% Ni, 6% Mo, 0.15% N, balance Fe); Turballoy 13 (0.15% C, 18% Cr, 24% Ni, 2.5% Mo, 1% W, 1.5% Ti, 1.5% Al, balance Fe); and Alloy 1336 (0.20% C, 19% Cr, 16% Ni, 49% Co, 12% W, 1% Nb, 2% Fe). Metallographic examinations were also employed to supplement the X-ray data.

The principal carbide was iden-

*Digest of "Microconstituents in High-Temperature Alloys", by H. J. Beattie and F. L. VerSnyder, ASM 1952 Preprint No. 1.

tified as M_6C using both copper and chromium radiation. Measurements of interplanar spacings with a spectrogoniometer yielded values of $a_o = 11.00$ Å $\pm$ 0.03. No attempt was made to identify what combinations of chromium, cobalt, molybdenum, tungsten, niobium, titanium, iron and others might be represented by the "M" of the formula.

Additional carbides of the $M_{23}C_6$ type were listed for 16-25-6 and 1336 in a few instances. The scarcity of data suggests that this carbide form (and perhaps $M_{21}M'_2C_6$?) exists only occasionally in these alloys.

Considerable X-ray data were presented to show the existence of titanium carbonitrides. Two varieties, one carbon-rich and the other nitrogen-rich, were listed for M252. Each showed practically no variation in parameter for a miscellaneous assortment of heat treatments in spite of the fact that the discussion proposes the existence of a continuous solid-solution system, TiC-TiN.

This proposal appears rather reasonable, but a similar variation in parameter between the two extremes [of 21 diffraction patterns for M252, only 2 show an intermediate value of a_o for Ti(C, N)] would therefore be expected unless some unappreciated factor in melting procedure has played an unexpected role.

A new phase was reported for Alloy 16-25-6; this phase was produced when the alloy was soaked 2 hr. at 2300° F. and then charged directly into a furnace at 1500° F., held 8 hr. and finally air cooled. This phase, appearing as thin needles in the microstructure, was deduced to have a hexagonal lattice with $a_o = 2.84$ Å and $c_o/a_o = 1.61$. It was proposed, on the basis of similarities in structure type and size of Cr_2N, Mo_2C and MoN, that the hexagonal lattice contains alternate basal layers of chromium and molybdenum atoms with nitrogen atoms occupying the interstices. Without further proof this compound was assumed to be $CrMoN_x$, where x lies between 1 and 2, depending on the degree of nitrogen saturation.

The crystallographic structure for this phase was derived from X-ray diffraction patterns of electrolytic residues, but the authors give no proof that these residues are exclusively the "needles" observed in solid metal under the microscope.

Two further structures of the hexagonal type (Laves compounds) were reported. One of these was found in two samples of M252. The structure in each instance was reported as having $a_o = 4.734$, $c_o/a_o = 1.63$ with 12 atoms per cell.

The second Laves compound was reported as existing in as-cast Turballoy 13 but disappearing upon heat treatment; this was identified as Fe_2Al. No comment was made concerning the fact that the *Metals Handbook* lists the iron-aluminum system as body-centered cubic in the region from 0 to about 52 atomic percentage aluminum, with evidence of ordered structures at Fe_3Al and FeAl. This constitutional diagram appears incompatible with the idea of a hexagonal Fe_2Al structure.

The authors appear to have carried out a meticulous and careful program of experimentation. Their data seem to be in excellent agreement with the results of other workers. The interpretations of certain of their diffraction patterns seem, however, to be based more on interesting analogies and inferences than upon direct evidence. These interpretations also require the assumption that the phases observed under the microscope have all undergone electrolytic separation without change or loss of structure, an assumption that requires a fair degree of confidence.

J. A. FELLOWS

Tempering of Martensite*

PREVIOUS WORK on the tempering of a medium alloy steel showed that the high silicon content of this steel, about 1.5%, prevented softening during tempering in the range 300 to 700° F. Since there was little indication in the literature that this effect of silicon in retarding tempering was appreciated, it was decided to attempt to establish the mechanism of this effect. It had already been determined that the effect of silicon on tempering is the same in all steels, therefore most of the work was done on 4 steels: 0.6% carbon, 0.8% manganese-base composition with 0.4 and 2.2% silicon; and a 0.4% carbon, 3.0% nickel-base composition with 0.5 and 2.2% silicon. These steels were oil quenched after being austenitized for 1 hr. at 1600° F. Subsequent cooling in liquid nitrogen was used in some tests.

*Digest of "The Effect of Silicon on the Tempering of Martensite", by A. G. Allten and P. Payson, ⊕ 1952 Preprint No. 10.

Curves of Rockwell C hardness versus tempering temperature for a tempering time of 2 hr. showed the following behavior for both the 0.6% carbon and the 3% nickel steels: *(a)* The decrease in hardness up to 300° F. was essentially independent of silicon content. *(b)* In the range of about 300 to 600° F., the rate of softening decreased in proportion to the increase in amount of silicon. *(c)* The rate of softening began to increase again at about 600° F. in the 0.6% carbon steels and at 550° F. in the 3% nickel steels. *(d)* At about 800° F. the *rate* of softening was greater in the highest silicon steels, but at 900° F. (the highest temperature studied) the hardness was in the order of increasing silicon content.

The cause of the retardation of softening by silicon was investigated. Solid-solution hardening was not a likely answer, nor was dispersion hardening by precipitation of a silicon compound. Data from dilatometer runs showed that an increase in silicon content produced an increase in the temperature at which the contraction corresponding to the third stage of tempering was observed. This temperature increased from about 500° F. at 1 atomic percentage silicon to 800° F. at 6 atomic percentage silicon. The latter temperature appeared to be almost the limit to which the third stage of tempering can be suppressed by additions of silicon. Electrical resistivity data indicated that there was no decrease in the amount of silicon in solid solution at any of the tempering temperatures. X-ray methods were used to study various aspects of the tempering process and showed that the coherent transition precipitate presumably persists in metastable equilibrium with carbon dissolved in martensite to temperatures up to 700° F. in the high-silicon steel.

While the question of how silicon retards tempering was not answered by the experiments described, it was suggested that greater amounts of energy, in the form of increased tempering temperatures, are needed to nucleate cementite as the silicon contents of the steels are increased. The observed resistance to transformation of the retained austenite in high-silicon steels may be directly related to the formation of cementite. Also, the initial coherent precipitate may grow and tend to strain the matrix during tempering in the temperature range below that at which cementite forms.

A. G. GUY

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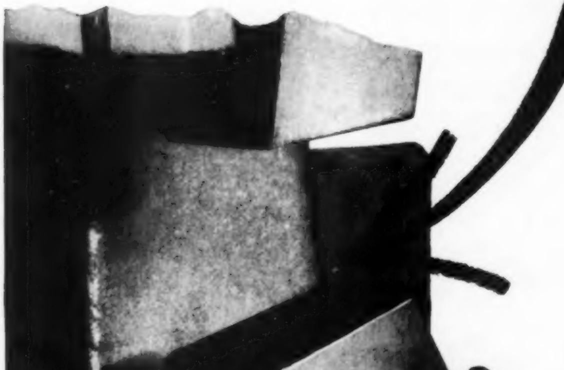

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Properties of Austenite and Sigma*

THIS PAPER deals with a specific alloy from which austenite and sigma phases were separated by selective anodic dissolution methods after the alloy had been given suitable heat treatments. Some of the physical and chemical properties of these separated phases then were determined.

Particularly interesting is the evidence, found by this means, of microstresses in the austenite of the massive alloy. Since it seems to be generally believed that the transformation from austenite to martensite can only take place under the action of tensile stresses, these microstresses probably are compressional in nature. In the massive material, the austenite was stable at room temperature and transformed martensitically only when cooled to −321° F. However, after dissolution, this same austenite in the extracted form had transformed martensitically when cooled to room temperature.

Further evidence was found of the increasing tendency of austenite to transform martensitically after extraction as the time of its formation at 1560° F. was increased, and of the stability of the untransformed (retained) austenite to low-temperature treatment. The only change noted with time of heating at 1650° F. was a slight tendency of the chromium content to increase. Since there is a general belief that there is no compositional difference between martensitically transformed austenite and retained austenite, this suggests that a more careful examination of this factor might prove fruitful. Likewise, the tendency of some sigma compositions to become ferromagnetic at about −171° F., whereas others seem to be stable against this change, also requires further explanation.

The data given by the authors for the differences in composition between the austenite, ferrite and sigma phases which were in equilibrium are particularly welcome because of the assistance they will give in understanding some of these phase changes and equilibrium relationships. Although there is no question of the validity of the authors' statement that corrosion

(Continued on p. 138)

*Digest of "The Electrolytic Separation and Some Properties of Austenite and Sigma in 18-8-3-1 Chromium-Nickel-Molybdenum-Titanium Steel", by T. P. Hoar and K. W. J. Bowen, ⊕ 1952 Preprint No. 4.

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Properties of Austenite and Sigma

(Continued from p. 136)

weakness of the austenite caused by chromium impoverishment need not necessarily be expected in sigma-containing structures of the particular 18-8-3-1 alloy studied, it should be pointed out that this composition probably lies fairly close to the lower chromium limit of the sigma-forming regions, and that this aspect must be taken into account, particularly when considering alloys containing larger amounts of chromium. The tendency of the austenite, when sigma forms, always must be to approach a composition lying at the higher chromium edge of the austenite phase field, and, in still higher chromium alloys, this composition may contain markedly less chromium than the average composition of the original alloy. This is equivalent to saying that the greater the amount of chromium-rich sigma precipitated, the greater will be the chromium impoverishment of the remaining austenite.

The observation that, at least in the solutions tested, the sigma phase becomes passive more rapidly after exposure to air after abrasion than does the austenite, is of some practical interest because of a fear by many that the reverse situation would obtain. The authors show that any selective corrosion would be expected to be of a relatively general type rather than a concentrated type of pitting attack affecting primarily the sigma phase. However, they also wisely point out that, with acid or other oxygen-free conditions under which the passivity of the sigma (which makes it noble to the austenite) may be expected to break down, sigma becomes the phase more likely to be attacked preferentially. These conditions undoubtedly would result in pitting. Their results also seem to indicate that as a result of the greater tendency of the sigma phase to become ennobled by becoming completely passivated (in comparison with the austenite phase), somewhat greater general corrosion may occur when the alloy is sigmatized than when it is completely austenitic.

An intelligent application of the authors' results should permit rationalization of many of the now puzzling observations in connection with the corrosion of some stainless steels, particularly under accelerating conditions. C. H. SAMANS

Order-Disorder Transformation*

THIS PAPER presents an interesting new idea in physical metallurgy. The modern viewpoint considers order-disorder transformation as a *homogeneous* change of state. Sometimes it is described as a second-order transformation from analogy with established second-order transformation, namely magnetic transformation. This modern viewpoint predicts continuous change of structure-sensitive properties, resulting from continuous change in atomic arrangement, such that segregation into *distinct* ordered and disordered masses is not admissible, even though equilibrium is maintained.

The authors argue against this viewpoint. They endeavor to demonstrate that these transformations are true *heterogeneous* phase changes in the full sense of the classical viewpoint (Gibbs Phase Rule), even when ordering involves no pattern change in lattice sites.

Characteristics used as primary criteria of classical transformation in developing the argument are:

1. At equilibrium, structure-sensitive physical properties undergo *discontinuous* changes with temperature; where equilibrium is univariant the property change occurs isothermally; where equilibrium is divariant the change occurs within a sharply defined temperature interval.
2. The phases concerned are capable of *coexistence*, at equilibrium, within the temperature interval of transformation and should there be distinguishable as individually homogeneous masses of finite size, separated by sharply defined interfaces.

It is contended that these characteristics are associated with order-disorder transformation only when equilibrium is maintained and are absent when care is not taken to bring about equilibrium.

The authors' argument is based upon experimental re-examination of certain order-disorder transformations, and literature survey pertaining to this type of transformation. Their work was done on copper-gold alloys in the neighborhood of the ideal Cu_3Au composition (25 atomic percentage gold), and upon copper-zinc alloys in the

(Continued on next page)

*Digest of "The Order-Disorder Transformation Viewed as a Classical Phase Change", by F. N. Rhines and J. B. Newkirk, 1952 Preprint No. 12.

Order-Disorder Transformation

(Continued from p. 139)

$\alpha+\beta$, β, and $\beta+\gamma$ ranges. These two systems were chosen because ordering proceeds without any change in the pattern of lattice sites. It is pointed out that a careful survey of recorded experimental observations has shown conclusively that the distinguishing characteristics of classical transformation are present for all systems in which a change of crystal structure accompanies ordering and for which results of many equilibrium studies have been reported.

New evidence obtained from studies of the temperature variation of electrical resistance, X-ray diffraction, and rate of ordering is presented in support of their contention that the order-disorder transformation is a classical transformation. Great care was taken to attain equilibrium during studies.

The resistivity data are presented as evidence of the discontinuous nature of the order-disorder transformation under equilibrium conditions. The authors point out that sharp resistance discontinuities have also been found in other investigations in which equilibrium was established before making measurements. Dilatometric studies and lattice parameter studies of copper-gold alloys also have shown sharp discontinuities through the transformation interval. This is all in accord with characteristic cited under 1 of classical transformation.

The X-ray data are presented as direct proof of the coexistence of an ordered and a disordered phase at equilibrium within the transformation interval. The X-ray diffraction pattern for a copper-gold sample stabilized within the transformation interval and water quenched was compared to the patterns of a sample treated to produce complete disordering and a sample treated to produce full ordering. The pattern of the sample stabilized in the transformation interval showed all of the lines of both the disordered and the ordered patterns. Thus, this alloy at equilibrium at such a temperature is composed of two distinct states of crystalline matter, the one ordered and the other disordered. The most interesting piece of work by other investigators was with the well-stabilized alloys near the CoPt composition, because phase coexistence was also confirmed by microstruc-

(Continued on p. 142)

Order-Disorder Transformation

(Continued from p. 140)

tural examination. Superimposed order and disorder diffraction patterns were found; and, microstructurally, a clearly defined Widmanstätten pattern of ordered platelets was found disposed parallel to the dodecahedral planes in the disordered matrix crystal. These data satisfy characteristic 2 of classical phase transformation.

Extremely slow rates of ordering occur within the transformation interval and are taken as further evidence that ordering falls within the classical viewpoint. This viewpoint requires that the conjugate phases differ in composition when a transformation is divariant. The slowness of ordering is then attributable to two facts: *(a)* A structural change, requiring change in composition, must proceed by diffusion, which is commonly a slow process; and *(b)* when particles of a new phase form, some kind of nucleation process must operate, and this also may be expected to require substantial time.

It would seem that the authors have presented a clear case for considering the order-disorder transformation as a classical transformation, and that they have cast much doubt upon the modern viewpoint of this transformation.

R. W. Lindsay

Effect of Heat Treatments on Embrittlement*

Charpy impact blanks of SAE 3140 steel were water quenched and tempered for 1 hr. at 1245° F. The effect of twenty different thermal cycles on the propensity toward temper embrittlement was investigated. Specimens water quenched from the tempering temperature were reheated to an embrittling temperature of 930° F. at two different rates (30° F. per hr. and by heating in salt). Specimens were also cooled directly from the tempering temperature to 930° F. at two different rates obtained by quenching in salt and by slow cooling at 30° F. per hr. Isothermal embrittling treatments of 1 and 48 hr. at 930° F. were employed for each of the methods of heating

(Continued on p. 144)

*Digest of "The Effect of Various Heat Treating Cycles Upon Temper Brittleness", by L. D. Jaffe, D. C. Buffum and F. L. Carr, ⊕ 1952 Preprint No. 25.

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Effect of Heat Treatments on Embrittlement

(Continued from p. 142)

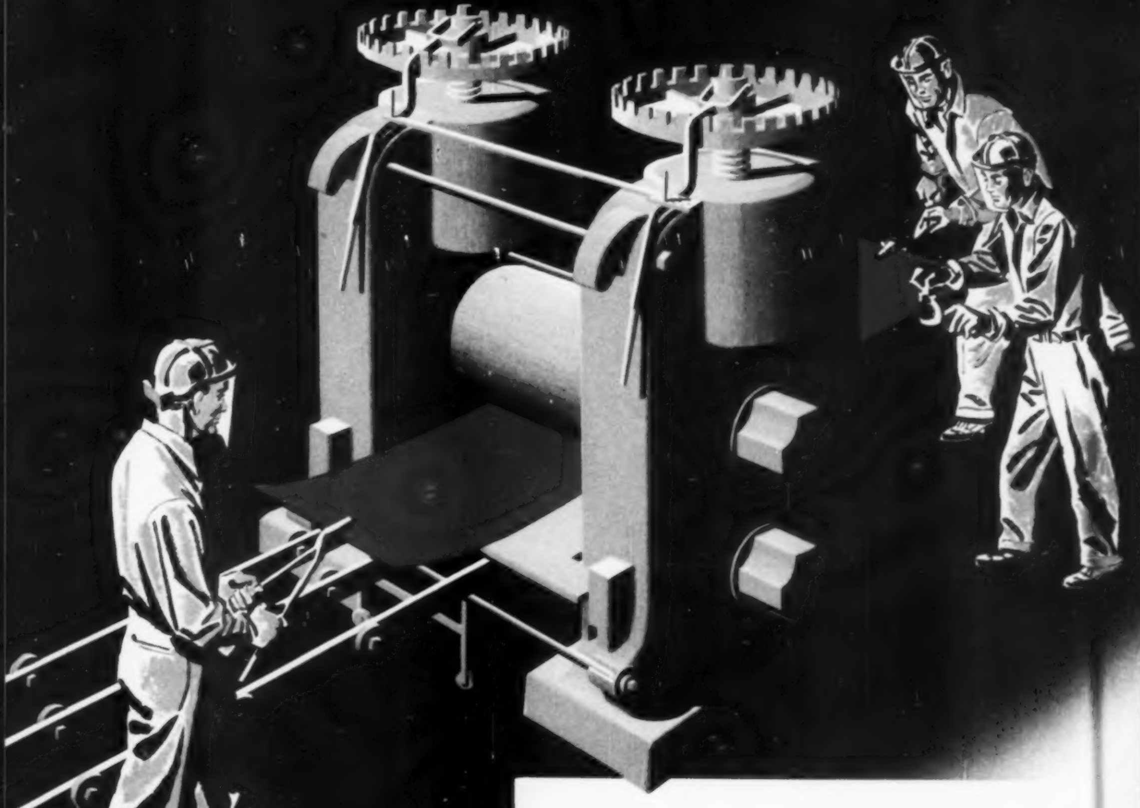
and cooling, and quenching in water and cooling at 30° F. per hr. to room temperature were employed following the isothermal period.

V-notch Charpy impact tests were conducted over a range of −256 to 176° F., so that complete transition curves were obtained. The increase of the temperature of transition from ductile to brittle behavior produced by a given thermal cycle was employed as a measure of the embrittlement resulting from that cycle. The transition temperature was chosen as the lowest temperature at which the fracture was 100% fibrous.

Treatments involving quenching to room temperature followed by rapid reheating to the embrittling temperature (930° F.) yielded the same transition temperature as those involving rapid cooling directly to the embrittling temperature. Cooling to room temperature from the tempering range had no effect on the severity of the embrittling reaction. Slow cooling from the embrittling temperature or slow heating from room temperature to the embrittling temperature produced the same amount of embrittlement; this may not be true above 930° F.

The amount of embrittlement resulting from slow cooling from 1245° F. to the embrittling temperature depended on the degree of embrittlement produced without the slow cool. The increase in the transition temperature resulting from the slow cool appeared to become progressively smaller as the amount of embrittlement without the slow cool increased. A similar behavior was observed for the effect of an isothermal hold at 930° F. In the use of several successive embrittling treatments, each contributed to the phenomenon — the amount induced by a treatment depending on the embrittlement already present.

The embrittlement resulting from slow cooling from the tempering temperature to the embrittling temperature was considerably greater than the amount of embrittlement resulting from slow cooling from the embrittling temperature to room temperature; that is, most of the embrittlement on continuous cooling occurred at temperatures higher than 930° F. Comparison of these results with those given in an earlier publication showed that embrittlement took place more rapidly on continuous cooling than during isothermal holding. R. F. Hehemann



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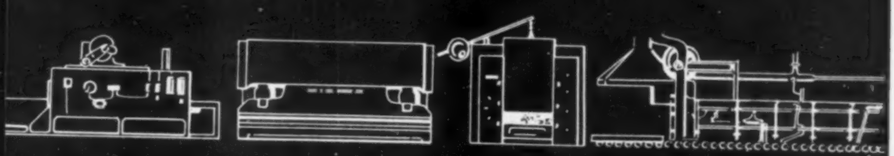


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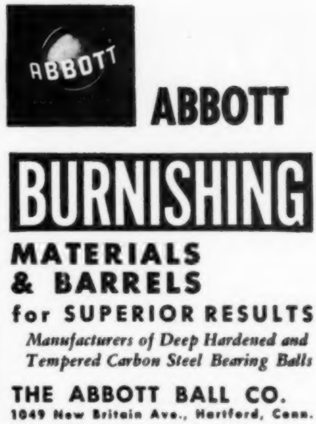

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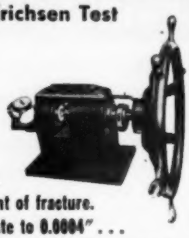

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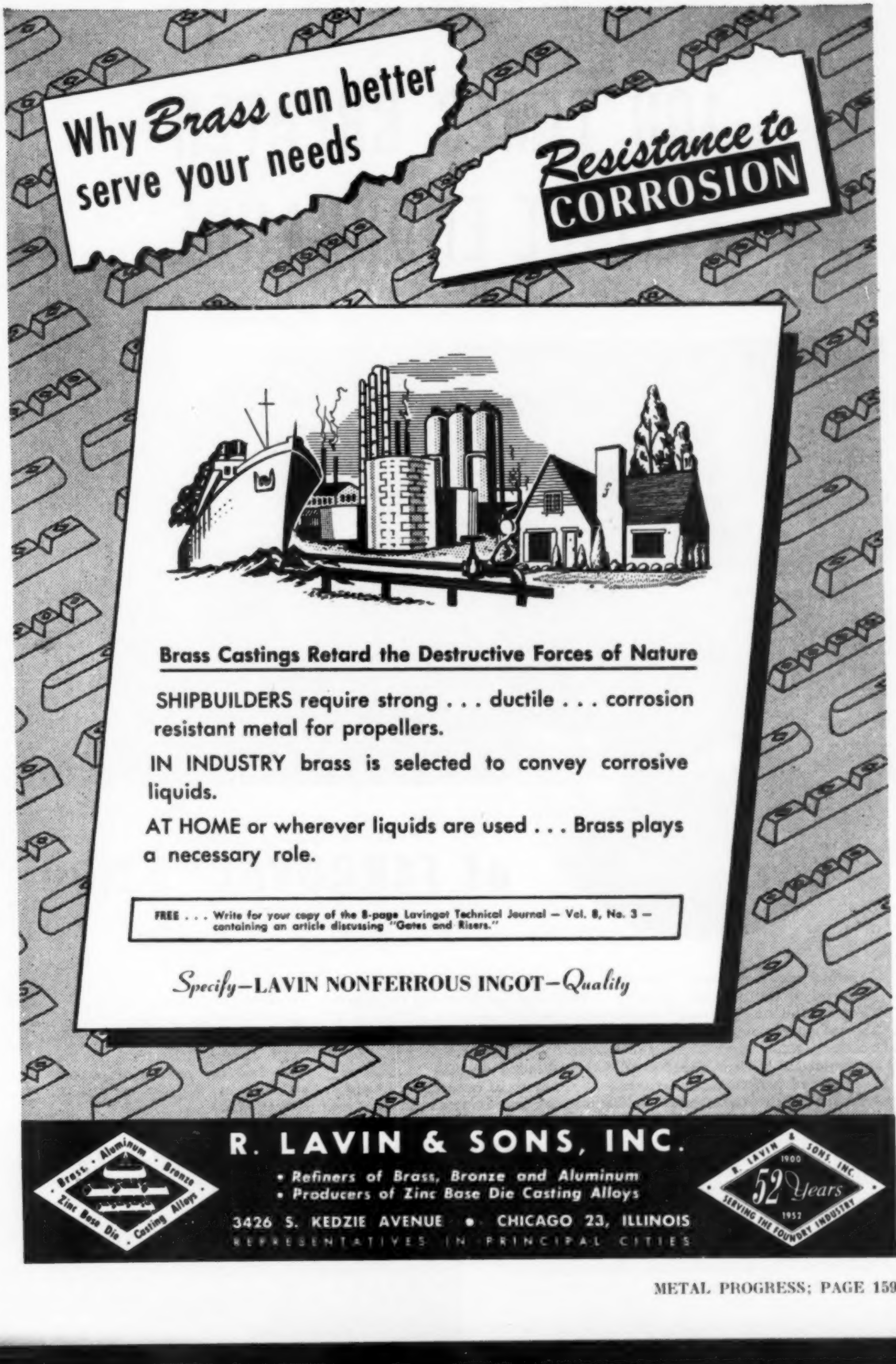

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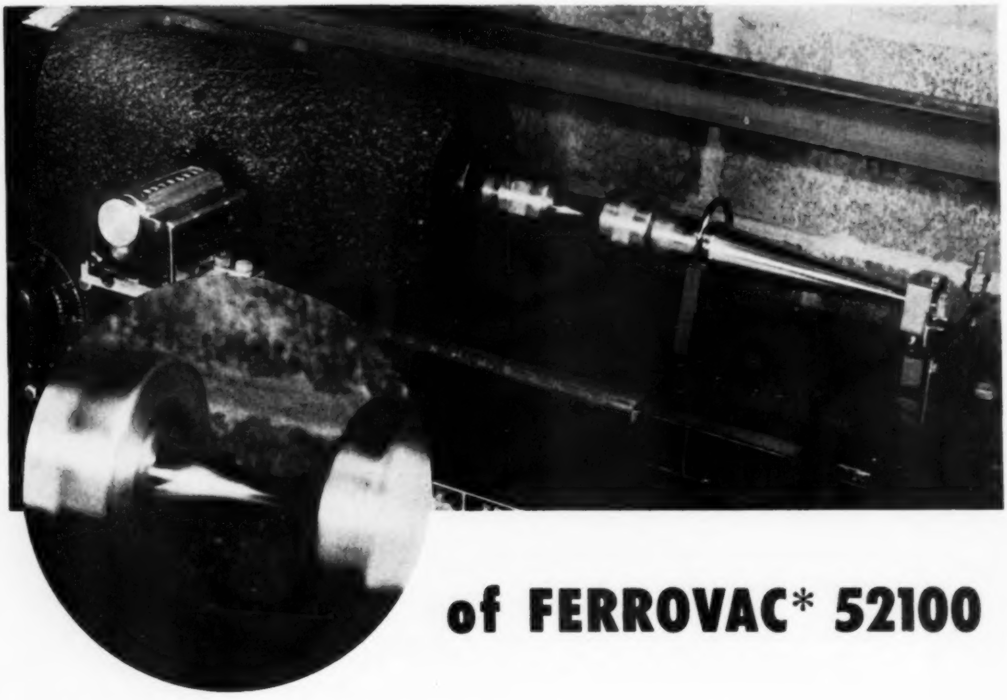

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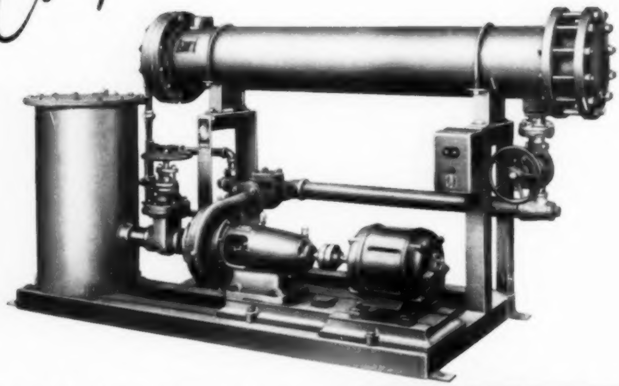

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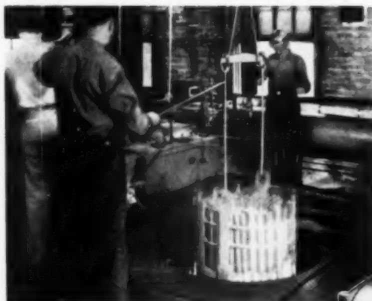

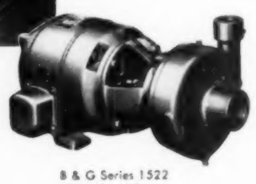

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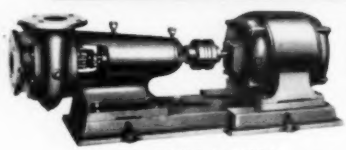

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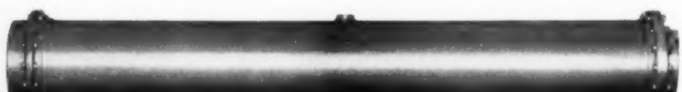

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Residual Stress in Toolsteels*

RESIDUAL STRESSES induced in steels by heat treatment and other operations can greatly affect their behavior in service. The control of these stresses is complex because of the phase transformations occurring during quenching and tempering. While the results of residual stress investigations on several quenched steels are available, the effects of tempering have not been completely illustrated. The work described in this paper deals with the distribution of quenching and tempering stresses in an oil hardening manganese steel (0.90% C, 1.30% Mn, 0.42% Cr, 0.42% W, 0.32% Si).

Stresses were induced in five flat specimens (2 x 2 x ½ in.) by oil quenching from 1475° F. After quenching, four of the specimens were tempered for 1 hr. at temperatures ranging from 425 to 1150° F. A sixth unhardened sample was given a stress-relieving treatment at 1100° F. Special precautions were taken throughout to protect the steel surfaces from carburization, decarburization and oxidation.

The magnitude and distribution of the residual stresses were determined in each specimen by an adaptation of the Bauer and Heyn technique. The procedure consisted of removing thin surface layers from the specimens while observing the resultant curvature changes by Letner's optical interference method. The stress values for the distributions were then calculated from a mathematical relationship between stress and curvature.

The removal of surface layers was accomplished by grinding, lapping and chemical etching. Experimental work was completed which indicated that when these were applied in the proper manner, the residual stress pattern was not affected. The data from the quenched steels indicated that the principal quenching stresses were tensile, of the order of 70,000 psi., and that these were equal in all surface directions. The maximum stress occurred at the surface, and almost all of the tensile stresses were concentrated within 0.025 in. of the surface (one-tenth of the specimen half-thickness). All of the remaining half of the specimen was occupied with smaller, balancing compressive stresses. *(To p. 164)*

*Digest of "The Effect of Quenching and Tempering on Residual Stresses in Manganese Oil Hardening Toolsteel", by H. J. Snyder, © 1952 Preprint No. 21.

Residual Stress in Toolsteels

(Continued from p. 162)

Tempering at successively higher temperatures progressively reduced the surface tensile stress, but did not appreciably affect the depth to which the main stresses penetrated. Tempering at 425° F. reduced the surface stress to about 50,000 psi., and at 650 and 800° F. to about 10,000 psi. The specimen tempered at 1150° F. actually showed a very slight compressive stress in the surface layers, but this is believed to have been caused during cooling from the tempering temperature.

The stress-relieved specimen also showed a residual compressive stress of 10,000 psi. at the surface which extended to a depth of about 0.020 in. This was attributed to cooling from the stress-relieving temperature.

While the authors note the importance of phase changes on the stresses induced during quenching and tempering, no references are made to the transformations occurring in this steel during treatment.

The failure of engineers to evaluate residual stress patterns can be traced to two things. The first is that in the many complex parts used in engineering, it is virtually impossible to accurately measure these patterns. The second is that the majority of quenched parts are given a tempering treatment of sufficient rigor to minimize the value of the as-quenched residual stresses. This paper effectively points up the effect of tempering on the residual stresses, indicating that a draw of only 650° F. will greatly diminish their magnitude while only moderately affecting the hardness.

F. X. Kayser

Hardness at Elevated Temperatures*

A rapid test for evaluating the mechanical properties of high-temperature alloys has been long sought. Hot hardness has seemed to be the best approach to this problem; however, investigators have differed on mechanism of test as well as on method. Dynamic and static methods have been evaluated extensively, but to date no correlation exists — primarily be-

(Continued on p. 166)

*Digest of "Hardness of Various Steels at Elevated Temperatures", by F. Garofalo, P. R. Malenock and G. V. Smith, Ⓐ 1952 Preprint No. 18.

Hardness at Elevated Temperatures

(Continued from p. 164)

cause of the difference in and the duration rate of indentation loading. Some degree of standardization has been evident among the test methods that utilize the static loading technique.

The authors describe a tester of the static load type which requires heating of the indenter and the specimen in an inert atmosphere, and which automatically applies a dead-weight load on the indenter while in contact with the specimen, the load also being removed automatically. Fully dried helium and hydrogen in combination with a titanium "getter" provides an ideal atmosphere. The electrically actuated loading mechanism permits a loading and unloading cycle of 1 min. each and duration of the total load on the specimen is approximately 1¾ min. Metallographically polished specimens (on which extreme care was used to eliminate the worked layer on the surface because of its detrimental effect on results) were used for the tests.

Hardness tests were made initially at room temperature with this apparatus as well as a standard Vickers machine for comparison purposes. A minimum of seven impressions are made at the temperature desired. The equipment is cooled to room temperature and the impression diagonals measured. Little error was encountered because of thermal contraction of the diagonals during the cooling cycle.

Evaluations on stainless austenitic steels, carbon steel and alloy steel are given at temperatures ranging from 1100 to 1500° F. for the former and 300 to 1400° F. for the latter two.

The Vickers diamond indenter was not satisfactory because the tip disintegrated somewhat after a dozen impressions at 1500° F. It was replaced by a sapphire indenter which did not develop any faults.

Data showing the comparison between hot hardness and rupture strength are shown. Scatter seems to be less for the short rupture times, such as 1 hr., and increases as the time-to-rupture increases. A relationship was observed between hot hardness and stress needed to cause a creep rate of 1% per 10,000 hr. In all tests, the relationship appears to be independent of structure, and of temperature within the limits investigated.

(Continued on p. 168)

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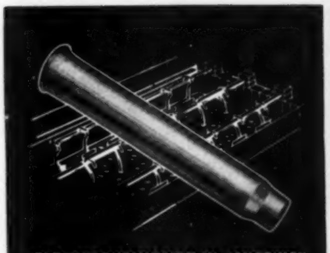

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Hardness at Elevated Temperatures

(Continued from p. 166)

The authors emphasize that further standardization of hardness testing at room and elevated temperatures should be concerned with the adoption of an accepted procedure for surface preparation, particularly for austenitic-type alloys.

R. A. Long

Effect of Hardness on Absorption of Impact Energy*

Groups of unembrittled specimen blanks of various hardness levels were produced from S.A.E. 3140 steel by tempering fully martensitic blanks. Tempering times were chosen so as to minimize embrittlement during tempering. Half of each group was then embrittled by holding for 48 hr. at 930° F.

Energy absorption versus testing temperature curves were drawn after breaking unembrittled and embrittled standard V-notch Charpy specimens of different hardness levels. It was noted from each curve that the energy level generally approached a constant value upon increasing the testing temperature above the transition zone. A plot was then made of these energy levels versus the corresponding hardnesses of the specimens for both the unembrittled and the embrittled condition. This plot presents certain interesting features: *(a)* For specimens of the same hardness, the energy level is higher for the unembrittled specimens by about 10 ft-lb. over the hardness range investigated (Rockwell C-22 to 32.5); and *(b)* a linear relationship exists between energy level and hardness in the range Rockwell C-27 to at least C-38, such that the impact energy decreases 4½ ft-lb. for an increase of 1 unit of hardness.

It seems to be implied that the early criterion of temper brittleness of a difference in energy absorption upon fracturing specimens at the same testing temperature might be usable if the unembrittled and the suspected samples were tested at the same hardness level.

R. W. Lindsay

*Digest of "Effect of Hardness on the Level of the Impact Energy Curve for Temper-Brittle and Unembrittled Steel", by F. L. Carr, M. Goldman, L. D. Jaffe and D. C. Buffum, ⊕ 1952 Preprint No. 26.

Indium-Arsenic Alloys*

The indium-arsenic phase diagram was studied by thermal, metallographic, and X-ray techniques. Alloys were prepared by melting weighed amounts of high purity indium and arsenic in evacuated and sealed capsules. In the thermal analysis employed to define the liquidus and solidus curves, alloys containing less than 39.5% (by weight) arsenic were studied under an argon atmosphere; however, because of the volatility of arsenic, alloys containing more than 39.5% arsenic were studied in evacuated and sealed capsules. The arsenic-rich end of the diagram was thus determined under a variable pressure.

A single intermediate phase occurred at the composition InAs with a melting point of 942° C. (1730° F.). This intermediate phase formed eutectics with indium and arsenic. X-ray studies of this phase indicated a face-centered cubic, zinc blende-type structure ($a_0 = 6.058_4$ Å). Lattice parameter measurements of alloys near the InAs composition showed no variation in the lattice constant with variation in composition; therefore, it was concluded that the single-phase region surrounding the intermediate phase was extremely narrow.

The eutectic reaction at the indium-rich end of the diagram occurred at 312° F. Composition of the eutectic, determined by metallographic examination of alloys containing 0.02 to 9.9% arsenic, was 0.02% arsenic. The lattice parameter of indium in the two-phase alloys at the indium-rich end of the diagram was not measurably different from that of pure indium. The solid solubility of arsenic in indium was therefore considered to be very small. Similar considerations for the arsenic-rich end of the diagram indicated that the solid solubility of indium in arsenic was also extremely small.

The eutectic formed between the intermediate phase, InAs, and arsenic occurred at a composition of approximately 82% arsenic and a temperature of 1348° F. The study of this portion of the diagram was conducted at a pressure considerably higher than one atmosphere because of the volatility of arsenic. Since liquid arsenic exists at pressures above 36 atmospheres, it was assumed that the arsenic-rich portion as drawn in the diagram represents a condition at this pressure.

R. F. Hehemann

*Digest of "The Indium-Arsenic System", by T. S. Liu and E. A. Peretti, ASM 1952 Preprint No. 40.

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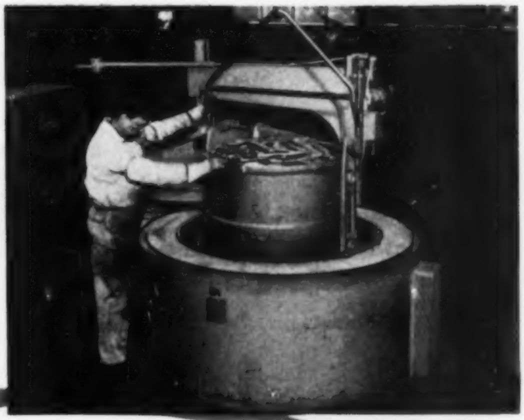

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Creep-Rupture and Recrystallization of Monel*

THIS WORK is a part of an extensive study of the behavior of metals and alloys under strain at elevated temperatures. Monel rods (of normal chemical composition) were used in the annealed and in 30 and 75% cold worked conditions for the creep-rupture tests; for the recrystallization studies the rods were cold worked 4 to 75%.

Using specimens of 0.25 in. diameter and 1.25 in. gage length, creep-rupture properties were determined over the temperature range of 700 to 1700° F.; the duration of tests varied from 0.001 to 2700 hr. and standard A.S.T.M. procedures were used.

At 100 hr., the values for annealed rods ranged from approximately 70,000 psi. at 700° F. to 8000 psi. at 1300° F.; from 95,000 psi. at 700° F. to 4000 psi. at 1300° F., and to 700 psi. at 1700° F. for the 30% cold worked material; and from 55,000 psi. at 900° F. to 7000 psi. at 1300° F. for the 75% cold worked material. Good resistance to oxidation is obtained up to 900° F., but from 900 to 1300° F. the oxide penetrates the grain boundaries — a condition related to intercrystalline cracking. These data confirm those of other investigations that cold worked Monel is less suitable than annealed Monel for creep service above its recrystallization temperature.

The Grant and Bucklin method of graphically extrapolating and interpolating the short-time, creep-rupture data works well with Monel.

Hardness, electrical resistivity, X-ray and metallographic studies were made of specimens which were cold worked from 4 to 75% and annealed from 0.5 to 500 hr. at 800 to 1700° F. Recrystallization begins at approximately 1145° F. for 75% cold worked material and at 1650° F. for 4% cold worked material.

Recrystallization occurs during creep-rupture testing and reduces strength because of the formation of fine grains along original grain boundaries. Recrystallization in the creep-rupture bars occurred at lower temperature and shorter times than was predicted from the static tests which were measured by hardness.

The equicohesive temperature is 700° F. for a strain rate of 0.1% per hr. in the 30% cold worked alloy.

W. A. MUDGE

*Digest of "Creep-Rupture and Recrystallization of Monel From 700-1700° F.", by N. J. Grant and A. G. Bucklin, ASM 1952 Preprint No. 5.

Mechanical Properties of Titanium and Titanium-Base Alloys*

The tensile properties of commercially pure titanium were investigated by Rosi and Perkins, in the temperature range of −320 to 1155° F., while Bishop, Spretnak, and Fontana investigated tensile and other mechanical properties of two of the high-strength titanium alloys over a temperature range (for the tensile data) of −320 to 77° F. The alloys tested were RC-130-B (containing 3.8% Al, 3.8% Mn, and 0.24% C) and Ti-150-A (containing 1.3% Fe, 2.7% Cr, 0.08% max. Ni, and 0.05% max. C).

For the tensile tests of commercially pure titanium, two strain rates were used, 0.003 and 0.138 $min.^{-1}$. The strain rates used for the alloys are not given. Since some of the tensile tests on the alloys were made at temperatures where the behavior was essentially brittle, it would seem that the strain rate should be given, in view of the known importance of strain rate on the ductile-brittle transition in other metals.

For both the commercially pure titanium and the two alloys, yield point phenomena were observed in the tensile test in certain temperature ranges. For the commercially pure titanium, no well-defined yield point was observed in the ordinary stress-strain curve at the lowest temperature of testing. As tests were run at progressively higher temperatures, a well-defined double yield point appeared at 251° F. and was noted at temperatures up to 539° F. At higher temperatures the effect is less pronounced. For the alloys, a tendency to exhibit a double yield point is evident at room temperature, and a fairly definite (though not a double) yield point is observed even at the lowest test temperatures used.

For commercially pure titanium, strain aging was revealed by several discontinuities which were noted in plotting mechanical properties against tempering temperature. For example, in the range 500 to 845° F., there is a decrease in ductility with increasing tempera-

*Digests of "Mechanical Properties and Strain Aging Effects in Titanium", by F. D. Rosi and F. C. Perkins, ⊕ 1952 Preprint No. 29, and "Mechanical Properties, Including Fatigue of Titanium-Base Alloys RC-130-B and Ti-150-A at Very Low Temperatures", by S. M. Bishop, J. W. Spretnak and M. G. Fontana, ⊕ 1952 Preprint No. 31.

ture, and there is no change in yield strength with increasing temperature in the range 665 to 1025° F. At the higher of the two strain rates used, the strain-aging effects are not quite so great.

The commercial titanium showed all the other usual mechanical effects associated with strain-aging. After an initial prestrain, aging both at room temperature and at higher temperatures resulted in the appearance of a yield point when testing at room temperature. These effects can probably be attributed to small amounts of nitrogen and carbon known to be present in the material. The authors attribute the yield point at room temperature for the alloys to interstitial atoms in solution in the body-centered beta phase.

Ti-150-A had slightly higher yield and ultimate strengths than RC-130-B, except at the temperature of liquid nitrogen (−321° F.); at this temperature RC-130-B showed a slight gain in yield and tensile strength. Elastic moduli of both alloys increased at low temperatures, the increase being greater in Ti-150-A. Both have far higher yield and ultimate strengths than pure titanium over the temperature ranges covered by both test series.

Except for the tests conducted at lowest temperatures, the fractures in commercially pure titanium were of the ductile type. Tensile fractures for the alloys also were brittle at lowest temperatures, but fracture data at higher temperatures are not given. In one tensile test on a coarse-grained sheet specimen of commercially pure titanium, Lüders' bands were observed. These bands were found to consist of clusters of fine parallel lines, which X-ray analysis showed to be traces of {10$\bar{1}$0} planes.

Much of the tensile testing of the commercially pure titanium was done in liquid media. It is known that the results of tensile tests are sometimes different when the test is conducted in a liquid medium than when conducted in a gas, even though the temperature is the same.

In both series of tests, plotting of true stress versus true strain for all tests would be helpful in gaining an understanding of the materials useful in engineering.

In the case of the alloys, several other types of tests were made in addition to tensile tests. Impact and hardness tests were run at temperatures down to −423° F. RC-130-B is slightly harder than Ti-150-A at all temperatures. The hardness of

(Continued on next page)

Titanium and Titanium-Base Alloys

(Continued from p. 175)

both materials was increased about 107% at a temperature of −423° F.

Fatigue tests using both polished and notched specimens were run at room temperature, at −108 and −321° F. The endurance limits of both alloys were raised at low temperatures, but RC-130-B showed the greater increase. Ti-150-A suffers a greater loss in fatigue strength as a result of notching than RC-130-B, but Ti-150-A has a substantially higher fatigue strength at all test temperatures.

H. B. Goodwin

Butt-Welding Paper-Thin Stainless*

Some interesting problems arose in the manufacture of tiny structural shapes of stainless steel (I-beams, channels, angle bars) for scale models of submarine hulls. The webs and flanges were from 0.005 to 0.025 in. thick, and the maximum dimension was about $\frac{1}{16}$ in. The problem was solved by holding the parts accurately in jigs attached to an ordinary milling machine table. An electrical terminal took the place of the cutter, properly insulated from the flame, and connected to a bank of capacitors and transformers. The conventional motions of the cutter head and table could be used to produce automatically the necessary pressure at successive locations along the seam.

Voltage must be controlled to within 3% of optimum, and electrical discharge shortly before maximum pressure was applied mechanically. Size of electrode is also critical to avoid burning (if too large) or poor welding (if too small).

The relatively large difference in area between the flange and web of a T-joint results in the web's burning or sputtering away before the flange can be brought to welding temperature. Bathing the material in alcohol during welding improves conditions, either due to cooling from evaporation of the alcohol, by reducing oxidation, or contamination from the electrode.

Fabrication of a 10-in. length of a model I-beam requires about 240 individual welds. When properly set up, "production" is 12 per hr.

*Digest of "Successful Welds Made by New Technique", *Report* of U. S. Naval Ordnance Laboratory, August 1952, p. 4.

Electrochemical Production of Zirconium Powder*

Zirconium metal powder has been produced by electrolysis of a fused sodium chloride – potassium hexafluozirconate (K_2ZrF_6) mixture, using a graphite crucible as anode and a graphite rod as cathode. With a charge of 5 to 6 lb. of electrolyte held at 1380 to 1470° F., it has been possible to produce 120 to 200 g. of pure zirconium in 2 to 3 hr. The product is a strongly coherent mass of coarse particles, having a bulk density of 2 g. per cc. after being separated (50% held on a 100-mesh sieve). It is low in oxygen and nitrogen, and can be consolidated by arc melting to yield a ductile product. The "double-drip" melted zirconium had a hardness of about Rockwell B-81, and was capable of being cold rolled to 71.5% reduction before edge cracking became evident. Hardness values rose to B-100 during the rolling operation.

A wealth of detail is given concerning the design of the graphite resistance furnace, the graphite electrolytic cell, the operating cycle, and the equipment used for purifying argon for the maintenance of an inert atmosphere. The furnace is mounted inside a welded, heavy steel container to permit evacuation of the furnace and purging with purified argon. It is essential to remove all traces of oxygen, nitrogen, moisture, and other reactive gases from the argon. This is accomplished by passing it over calcium hydride (CaH_2) at 570° F., copper oxide (CuO) at 1020° F., through phosphorus pentoxide (P_2O_5) and magnesium perchlorate [$Mg(ClO_4)_2$] to remove moisture, and through a column of titanium metal sponge at 1830° F.

The resistance furnace, energized by means of an alternating-current welder, uses about 250 amp. at 20 v. When the charge has melted and has been purged by means of a "pre-electrolysis" step lasting 1 hr. or more, the deposition of zirconium is carried out using a current between 100 and 200 amp. at a potential varying from 3 to 10 v. The rate of deposition of zirconium is around 0.83 g. per amp-hr.

Before being arc melted, the

(Continued on p. 180)

*Digest of "The Production of Zirconium by Fused Salt Electrolysis", by Merle E. Sibert and Morris A. Steinberg. Unclassified Report No. NYO-311 on U. S. Atomic Energy Commission Contract No. AT(30-1)-1144, Jan. 1, 1952. Available on loan from Technical Information Service, U.S.A.E.C., Oak Ridge, Tenn.

Electrochemical Production of Zirconium Powder

(Continued from p. 178)

crushed deposits are washed repeatedly with hot water and with dilute sulphuric acid. The powder is vacuum-dried after a final wash with alcohol. It is then compacted to briquettes at 40,000 psi. and arc melted (by a method described in a separate report).

Analyses for total zirconium, and for oxygen, nitrogen, and carbon have been made on all successful products. The analytical details are given in an appendix to the report. Briefly, in addition to a complete spectrographic analysis, zirconium has been determined as the pyrophosphate, oxygen by the anhydrous hydrogen chloride method or by use of dry chlorine, and nitrogen by a micro-Kjeldahl procedure. Carbon was determined by a "semi-automatic carbon determinator" by combustion to carbon dioxide, absorption in alkalis, and measurement of a change in volume.

The corrosion resistance of the resulting consolidated zirconium has been poor. This has been ascribed to presence of metallic impurities in the original zirconium salt which gives rise to undesirably large contaminations of iron and titanium. It is believed that these can be eliminated by a double recrystallization of the K_2ZrF_6.

The work is being continued to evaluate the effects of impurities and various types of treatments (cold working, annealing, hot working and such) on the physical and mechanical properties of electrolytically produced zirconium.

L. S. FOSTER

The Melting of Cast Iron Borings*

THE IRON FOUNDRYMAN well knows that when any sizable fraction of cast iron borings is mixed with the scrap and pig he charges into his cupola, the fine particles are oxidized too severely in the preheating zone of the stack before descending into the melting zone. Such fines are acceptable by blast furnaces, and most scrap dealers will segregate them — especially since it can be done very easily. In some areas the proportion of borings is considerable and it sells for half that of other metal.

(Continued on p. 182)

*Digest of "Swarf Injector for Cupolas", by A. R. Parkes, *Foundry Trade Journal*, April 10, 1952, p. 389.

The Melting of Cast Iron Borings

(Continued from p. 180)

The price easily justifies some expense for reclamation if the quantity is sufficient.

The usual American method of reclamation for own use and remelting (when the amount is sufficient) is briquetting under hydraulic press, operating more or less automatically, and producing small coherent chunks about the size of a potato — this, prior to cupola charging.

Now comes Arthur Croft of Crofts (Engineers) Ltd. of Bradford, Yorkshire, England, with the plan based on considerable experimentation of forcibly injecting untreated swarf (the English word for turnings, borings, sweepings and small junk) into the descending cupola charge just above the melting zone. A small hopper is attached to the side of the cupola and fed by a vertical chute leading down from an appropriate opening on the charge floor. There is a 1¼-in. mesh grid at the entrance to the chute and this normally rejects oversize material, and flow is assisted by an electrical vibrator.

The injector consists of an opening leading from the hopper through the cupola shell and lining at a slope of about 45°. The solids are impelled through this channel by a ram, operated pneumatically at time intervals determined by the foreman. Since at the entrance point in the shaft the charge constituents are normally at or over 1800° F. and the atmosphere is reducing, the entering borings assume a similar temperature, agglomerate quickly, and sink rapidly with the rest of the charge to the melting zone, where they melt without significant metallic loss.

The ram itself consists of a pointed steel shaft some 2 in. diameter to which are welded a number of shaped lugs at staggered intervals over about 12 in. of its lower end. The ram is mounted centrally in the duct, and by each stroke through the borings the lugs push forward a quantity into the furnace. There are, of course, various protective devices. At about 30 strokes per min. nearly 1½ tons of swarf can be pushed into the melting zone per hour.

A metallic balance sheet of a 36-in. cupola operating for three months under this system shows the following material melted: 990 tons pig iron, 25 tons purchased scrap, 81 tons steel scrap, 67 tons return castings (defectives), 425 tons cast iron borings, a total of 1588 tons of which the relatively large 27% went through the side-wall. The cleaned castings made from this metal weighed 1509 tons, showing a deficit of 5% due to spillage and loss in melting in about equal proportions.

Temporary stoppages of the injector for as long as 2 hr. have occurred while the furnace was working, without any difficulty in restarting.

The shaped firebrick at the entrance to the cupola melting zone is not unduly eroded in use, as this and the rest of the inlet chute and mechanism are cooled to some extent by the passage of the borings — a life is expected of six to eight months for this brick. No change in the melting rate is discernible, nor in the coke-to-metal ratio for securing hot clean iron.

(Some more serious doubts might be raised by American foundrymen about lining maintenance at the point of injection as well as uniformity of injection into a larger cupola. The experiences related indicate satisfactory operation on the relatively small cupola. How the injection process will compete with briquetting cannot be predicted.

S. F. Carter

Magnets of Pressed Powdered Iron*

ONE OF THE MOST important recent developments in permanent magnet manufacture has been the discovery that very fine particles of ferromagnetic materials, such as iron, exhibit permanent properties in contrast to the soft magnetic properties of the bulk material.

This phenomena in the magnetic properties of matter on a microscopic scale has been explained by the theories of L. Neel and has led to the manufacture of magnets by the Société d'Electrochimie d'Electrométallurgie et des Aciéries Electrique d'Ugine, Paris, France, from ultrafine particles of iron and iron-cobalt alloy. Magnets made from these materials are equivalent to the cast Fe-Ni-Al alloys and the Fe-Ni-Al-Co alloys. The particle size of the powders used is of the order of 100 to 1000 Å.

The ultrafine iron powder is prepared by decomposing a solid compound of iron or, for the iron-cobalt alloy, a mixture of solid compounds of iron and cobalt. Suitable compounds for this process are hydroxides, oxalates, carbonates and formates, but the formate is chiefly utilized. Frequently, a small amount of calcium formate (about 0.1% by weight) is added before the decomposition. The calcium formate breaks down to calcium oxide during the decomposition, but at the low temperature used the oxide is not reduced. This oxide effectively insulates the particles, thus preventing sintering during the compacting procedure.

Decomposition is carried out in an atmosphere of pure hydrogen at a temperature below 500° C. (930° F.). The time necessary for the decomposition is determined by the temperature and the properties desired in the powder. Because the powder is extremely pyrophoric, air must be excluded after the decomposition. This is achieved by immersing the powder in a nonreacting fluid medium such as gasoline. The powder is compacted while still wet.

Compaction is performed in a die, having the shape of the desired magnet, at a pressure of about 78,000 psi. The dimensions of duplicate samples can be held to a precision of ±0.0004 in. perpendicular to the direction of pressing and ±0.004 in. parallel to the direction of pressing.

The magnetic properties are influenced by the decomposition procedure and compacting pressures; properties can be varied 10 to 20% by a suitable selection of these variables. The compacts usually have a density of 0.16 to 0.18 lb. per cu.in. and are strong enough to resist the stresses usually encountered in mounting and using magnets.

Since these magnets are made by powder metallurgy techniques, the resulting product requires no machining or grinding. In addition, no sintering of the compact is necessary. This results in a lower cost of manufacture when a large number of duplicate components are required, and a saving of material that is normally lost in the machining and grinding operations or in rejects because of deformations produced in the sintering operation.

These magnets possess the same energy per unit volume as some of the cast magnets now in use but because of their lower density, utilization of powder magnets in place of cast magnets would result in an appreciable weight saving.

*Abstract of an unpublished report by J. Lamberton, 1951.

Welding of Titanium*

THE PRESENT CHAPTER in the expanding history of titanium can be considered to have started in 1946 with the first publication by Dean, Long, Wartman and co-workers of the pioneering pilot production of the Bureau of Mines. This detailed the promising physical and mechanical properties of titanium and was followed in a few months by a paper outlining the good weldability of unalloyed titanium ("Spot Welding of Titanium", by R. S. Dean, J. R. Long, E. T. Hayes and D. C. Root, *Metals Technology*, Vol. 13, October 1946, Technical Paper 2102). Since then, upward of half a dozen papers have appeared in the technical press extending the information on flash and fusion welding of titanium as well as its alloys.

This paper by Holt and Moore confirms previous findings and tabulates welding conditions for several types of welding. The authors state, "The welding conditions given here are in no way meant to be optimum conditions, but only a guide by which other conditions may be judged." A summary of their findings follows.

Spot Welding — A sheet of 0.40% carbon titanium was evaluated and best results were obtained with a press-type welder using single-phase alternating current of 100 kva., synchronous ignitron control, electrodes of Mallory 3 Metal which incorporated a fluted design, No. 2 Morse taper and a 3-in. radius face. The cold rolled sheet (0.060 in. thick) was degreased in carbon tetrachloride prior to welding. Weld time was 10 cycles using a weld force of 1000 lb. and a current of 9000 amp. The tension-shear strength of the weld joint was 2900 lb. for a 0.285-in. weld diameter. Decreased ductility in the weld zone was indicated by below normal tension strength (cross-tension specimen). In the light of the work by Mahla and Hitchcock, "Effect of Welding on Properties of Titanium-Carbon Alloys" (Research Supplement, Vol. 29, 1950, p. 544) which placed an upper limit of 0.25% on the carbon to preserve ductility, this lowered ductility was due, presumably, to high carbon content.

Flash Welding — The authors refer to the literature to indicate that some promising although very lim-

(Continued on p. 186)

*Digest of "Resistance and Fusion Welding of Titanium and Its Alloys", by E. F. Holt and W. H. Moore, *The Welding Journal*, Vol. 31, March 1952, p. 213-16.

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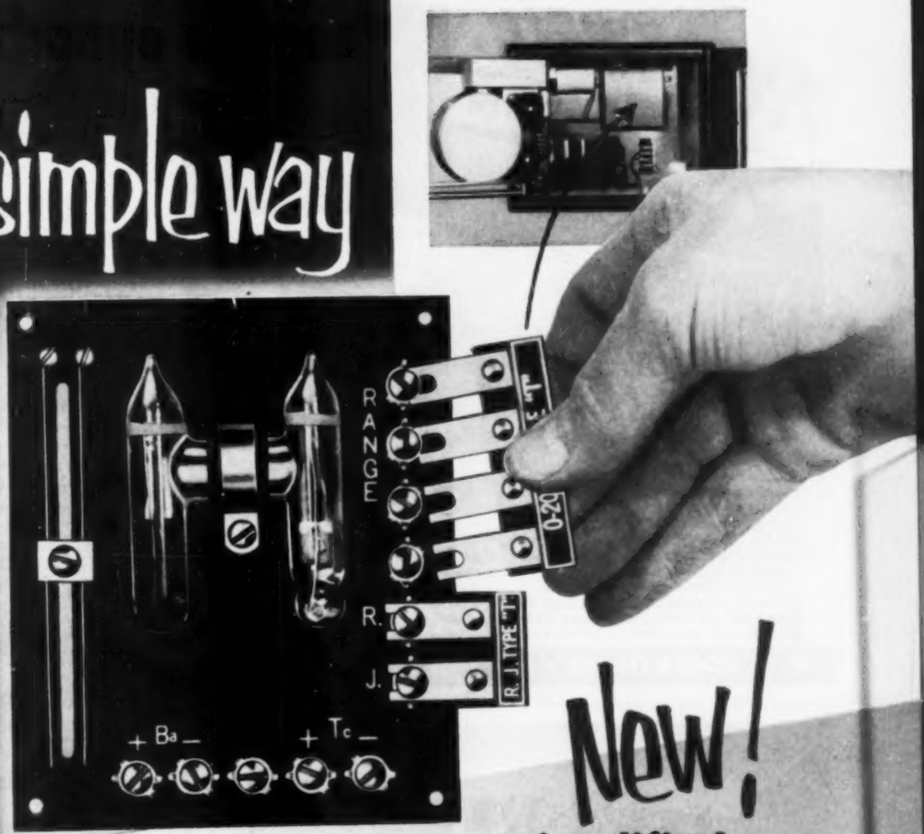

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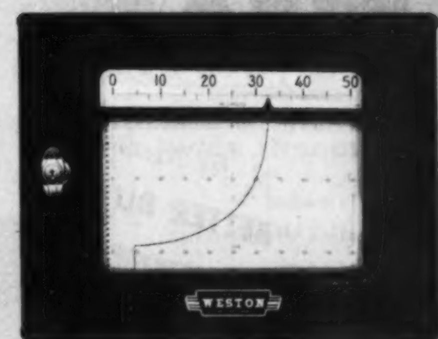

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Welding of Titanium

(Continued from p. 184)

ited work has been done with flash welding of titanium. They give the following conditions for the flash welding of $\frac{3}{16}$ x 3-in. titanium using copper alloy dies:

Die spacing:	
Initial	$\frac{7}{8}$ in.
Final	$\frac{3}{16}$ in.
Flash-off	$\frac{5}{8}$ in.
Upset	$\frac{3}{16}$ in.
Current cutoff	5 cycles
Flash time	4 sec.
Arc voltage	5.6 v.
Maximum secondary current	25,000 amp.
Static upset force	6,000 lb.
Work overhang in dies	Equal

Inert-Gas-Shielded Arc Welding — Shielded arc welding is confirmed as being readily accomplished. The authors prefer the use of an argon atmosphere, thoriated tungsten electrodes, direct current and straight polarity, and to exclude air from the underside of the weld by a tightly fitting backup plate or with inert gas. Typical conditions for butt welding ⅛-in. alloy plate are:

Current (direct, straight polarity)	85 amp.
Arc voltage	15 v.
Gas flow	6.2 l. per min.
Underside gas flow	10.6 l. per min.

W. F. FINLAY

Accelerated Corrosion Tests of Corrosion Resistant Alloys*

ACCELERATED corrosion tests were conducted in order to select an alloy having sufficient resistance to attack by acid fumes for its use in an air-duct ventilating system. Because the ducts would be subject to contamination by radioactive substances when in service, it was desirable to avoid the necessity of frequent repair or replacement.

For the tests, coupons of Monel, Inconel, nickel and Type 316 were suspended within an inverted beaker and above another beaker which contained boiling acid. The test conditions were such that the condensate dripped onto and ran over the specimens while a vigorous stream of air was directed over the surface of the liquid. A new set of specimens was exposed to each corrosive condition. The corrodents were dilute solutions of HNO_3,

(Continued on p. 188)

*Abstract of "Accelerated Corrosion Tests of Steels", Document LA 1313, Los Alamos Scientific Laboratory, Jan. 10, 1952.

Corrosion Tests

(Continued from p. 186)

HF, HI, HCl, and NH_4OH. In a later experiment, streams of SO_2 and air were directed at dilute, boiling HCl. The composition of the exit gas — calculated from the quantity of acid, water, and air (estimated from flowmeter readings) entering the apparatus — was found to be from 11 to 27% dry acid gas. The solutions were heated intermittently; the time of heating amounted to about one third of the total exposure time of 50 to 120 hr. Since the flow of air was continued during the hot and cold periods, the specimens had time to dry during the cold periods and thus the experiments became similar to a series of alternate immersion tests.

After each period of exposure the specimens were photographed, brushed clean in running water, weighed, and their thickness determined. Average corrosion rates were estimated both from total exposure time and from the length of time during which the solutions were boiled.

Susceptibility of the specimens to stress-corrosion was investigated by examining microscopically the base of saw kerfs, which had been made in order to identify the specimens. In two specimens of stainless steel where stress-corrosion was suspected, it was found that the tiny cracks were intercrystalline. Hence, it was unlikely that stress-corrosion had occurred.

Results of the test showed that Inconel had superior resistance to attack by HNO_3. Stainless steel withstood attack by HI and HCl better than did the other metals. Monel, because of its copper content, had the greatest resistance to attack by HF; Inconel was corroded less by HF than was stainless steel. The addition of SO_2 to the corrosive atmosphere had little effect on Inconel or stainless steel, although each were attacked slightly more than were Monel or nickel.

Data relative to unaccelerated tests made in a fume duct and laboratory hood in a chemical laboratory (supplied by W. Friend, International Nickel Co.) indicated that stainless steel had a slightly higher resistance to corrosion than did Inconel. However, Type 316 and other types of stainless steel pitted deeply. In addition, Inconel is known to have a low stress-corrosion susceptibility, while the austenitic stainless steels crack readily in many media containing halides.

J. T. Waber

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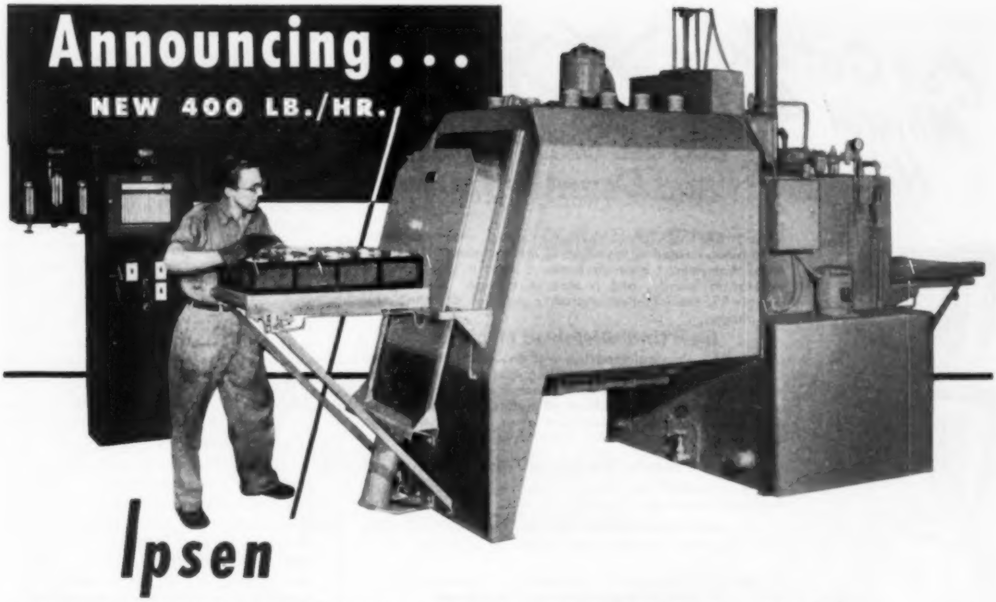

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Titanium — Metal and Alloys*

WHILE a \$125,000,000 business has been done annually in TiO_2, a white pigment, the metal was a laboratory curiosity until September 1948 when DuPont Co. began pilot-plant production. About 700 tons of metal were made by all producers in 1951; production at the beginning of 1952 was at the annual rate of 1400 tons. DuPont's first commercial-scale plant started in March 1951 at the rate of 50 tons monthly, and this will be increased by 50% by the end of 1952. The U. S. Bureau of Mines reports that governmental agencies are negotiating with industry to expand to assure production of about 7000 tons annually.

Among the many processes proposed, two have economic possibilities — one the decomposition of titanium iodide on a hot filament (see *Metal Progress*, February 1949, p. 193) which produces coarse crystalline sticks of metal. Second is the reduction of $TiCl_4$ by magnesium or calcium, which produces a sponge mass with a metallic appearance and contains a minimum of 99.3% titanium, and which must then be consolidated by powder metallurgical methods or by melting in a graphite or water-cooled copper crucible under electric arc (carbon or tungsten electrode) in an atmosphere of argon or helium. (Alternately, the DuPont process uses an induction furnace and a carbon crucible; this produces metal with up to 1% carbon which has poor formability and low impact strength.) Ingots of 1000 and 650 lb. have been cast from the respective furnaces.

Commercially pure titanium has ultimate strength of 90,000 psi., yield strength of 75,000 psi. and elongation of 20%. High-strength titanium alloys use Mn or Mn-Al (Rem-Cru Titanium, Inc.), Al-Cr-C (Mallory-Sharon Titanium Corp.) and Cr-Fe (Titanium Metals Corp. of America) as alloying elements. Nominal properties at room temperature are:

Type	Ult.	Yld.	Yld./	%
	(× 10³ psi.)		Wt.	El.
7 Mn	150	140	875	13.5
4 Mn, 4 Al	145	135		17.5
Al-Cr-C	165	153	950	10
1.8 Cr, 0.9 Fe	125	80	500	19
2.7 Cr, 1.3 Fe	150	130		16
3.0 Cr, 1.5 Fe	175	160	1000	11
24S-T*			410	
75S-T*			710	

*Aluminum Alloys

(Continued on p. 192)

*Digest of "Titanium Today", by R. S. Radcliffe, *Ordnance*, Vol. 37, July-August 1952, p. 166.

Titanium — Metal and Alloys

(Continued from p. 190)

In addition to these favorable strength-weight ratios, which persist to about 800° F., Charpy impact values on the high side, titanium is highly resistant to corrosion, particularly in respect to chlorine, chlorides and marine atmospheres. Studies at the U. S. Naval Experiment Station show titanium to be unusual in respect to its endurance limit, corrosion fatigue and cavitation in sea water and crevice corrosion.

Titanium can be forged from 1850 to 1450° F., and hot rolled from 1450° F. — both in normal atmosphere. Process annealing is at 1300° F.

Research on turbojet power units for aircraft shows the need of a new construction metal, particularly for the compressor end of the motor, where operating temperatures above 400° F. are being encountered in new designs.

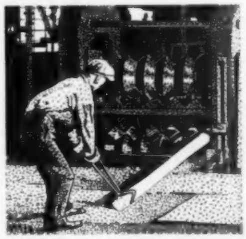
Titanium is also being considered by the airframe industry for parts of present and future planes, ranging from nuts, bolts, and other fasteners up to large sections requiring greater strength than aluminum and lighter weight than steel.

Because of its high melting point, titanium also makes a suitable fire shield up to 2000° F., since it will not burn through, even though it may ultimately have to be replaced.

O. A. Wheelon, in his report before an S.A.E. aeronautic meeting, sums up very aptly the possibilities of titanium for airframes:

"A preliminary analysis showed that a limited application of commercially pure titanium would make possible a saving of approximately 5% of the structural weight of a jet plane. Despite its high cost of $20 a lb. ($5 per lb. in sponge form), this use represented the most economical method for saving this critical weight, provided parts could be fabricated with reasonable means."

E. E. T.

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Corrosion of Zinc Plated Equipment*

Deterioration of zinc plated parts for telephone apparatus, after field storage in paper cartons and plywood boxes for more than normal periods of time, led to a study of the mechanism of this corrosion and a determination of corrective measures. The damage resulted from an unexpected strike which necessitated emergency storage under conditions which were admittedly poor. Standard finish on the parts was electroplated zinc 0.0002 in. thick which had been found adequate for normal indoor atmospheres.

Five types of test panels were packed in standard types of containers including corrugated paper, fiberboard, plywood and ventilated plywood boxes, all in general use for packaging of telephone equipment. The panels included *(a)* unfinished cold-rolled steel; *(b)* electroplated bright zinc 0.0002 in. thick; *(c)* same as *(b)* except for two-day aging at 215° F.; *(d)* same plus a proprietary chromate treatment; and *(e)* same plus a different chromate treatment. Finished panels were fingerprinted on one side to observe the reaction of this type of contamination.

A typical test cycle comprised two periods daily, one of 6 hr. during which time the temperature and relative humidity were maintained at 80° F. and 90%, and the other of 18 hr. with temperature at 100° F. and relative humidity at 90%. Duration of the test was 29 days.

Inspection after the test disclosed that, in general, the equipment packed in corrugated paper boxes had corroded less than that in the fiberboard boxes, and this in turn was attacked to a lesser degree than units in the plywood containers. It was also noted that corrosion of packaged equipment lagged behind unpacked items during the earlier part of the test but apparently accelerated as the test progressed and ultimately equalled or even surpassed it, particularly in the plywood and fiberboard boxes.

In view of the satisfactory results obtained with the chromate treatments on the test panels, it was decided to evaluate such finishes on shop finished products. Similar tests covering 21 days were made and it was again found the equipment packed in plywood corroded to a greater extent than that in cardboard. None of the treatments was completely effective in preventing corrosion from fingerprints, although some were better than others and most were effective in reducing white corrosion and fingerprinting on units packed in cardboard.

Experiments with a set of test panels in a plywood box lined with a lightweight corrugated paper showed less corrosion than on samples in an unlined box, leading to further study of different types of linings, treated and untreated.

All tests indicated that condensation of moisture was the principal cause of corrosion. However, the contributory effect of small amounts of contaminants emanating from the plywood was recognizable. As to mass effect of specimen, corrosion was less on the thin panels and grew worse as thickness increased.

The study gave assurance that zinc plated and chromate treated parts, packed in corrugated paper or plywood boxes lined with corrugated paper, would adequately withstand the severe storage conditions encountered originally.

A. H. Allen

*Digest of "Effect of Packaging on Corrosion of Zinc Plated Equipment", by K. G. Compton, S. M. Arnold, and A. Mendizza, Monograph 1927, Bell Telephone System.

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Effect of Sigma on Impact Properties*

By extending the limits of the sigma-forming compositions to higher nickel and chromium contents, the authors have contributed materially to the problem of eliminating sigma formation at elevated temperatures in iron-nickel-chromium alloys. The limiting chromium contents, above which these alloys will form sigma in the temperature range of 1200 to 1650° F., are now well established as being up to about 35% nickel for alloys of simulated commercial purity. The present extension, determined by metallographic means using the very dependable glyceregia etch, is in good agreement with the boundary reported earlier by Nicholson, Samans and Shortsleeve for alloys of lower nickel content. Because this earlier work was done by X-ray techniques, which are known to be somewhat less sensitive than the metallographic method for detecting small amounts of sigma, this agreement substantiates both data.

*Digest of "Sigma Formation and Its Effect on the Impact Properties of Iron-Nickel-Chromium Alloys", by A. M. Talbot and D. E. Furman, ASM 1952 Preprint No. 2.

It is difficult to believe that the apparent difference in the boundary between as-cast, annealed and cold worked alloy is real, even though the authors found no difference between the results secured after 1000 and 3000-hr. heat treatments. Since true equilibrium cannot depend upon the form in which the metal exists, particularly in relatively massive pieces such as were used, this suggests either that the as-cast material contained some highly effective additional impurity which was not detected by the chemical analysis used, or that the nucleation time for sigma formation in the as-cast metal (and, in some instances, in the annealed material as well) was so long that true equilibrium did not exist — even under the careful conditions used by the authors. Certainly, if the compositions of the three types are exactly the same, the data for the cold worked material must be considered as the closest approach to equilibrium. In this condition nucleation is known to have occurred, so diffusion becomes the controlling factor and the fact that no signifi-

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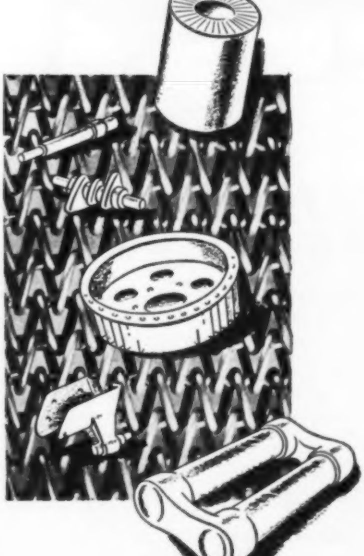

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Effect of Sigma on Impact Properties

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cant difference is found between the results after two long times of heat treatment becomes of importance. It is noted that, with the high-silicon alloys for which — for some unknown reason — the nucleation of sigma is quite rapid, no essential difference was found between the boundaries of the three conditions of the material.

The authors' data on the effects of small amounts of sigma on the room-temperature impact properties are valuable because so little attention has been paid to this characteristic in the past. Even though it is probable that this effect of sigma upon impact properties would not be so serious at elevated temperatures as it is at room temperature, these results emphasize that the use of sigma-forming alloys in the range of 1200 to 1650° F. (and possibly even as low as 1050 or 1100° F.) inevitably will lead to embrittlement. This is especially important in connection with applications in the chemical and petroleum industries where equipment must be shut down periodically for cleaning and general inspection. The careful handling that must be given to embrittled material under these conditions, and the ever-present hazard that it introduces, should make clear the importance of selecting compositions which will not deteriorate in this manner.

Because most of our commercial stainless and heat resisting steels are now made to specifications which fall entirely or partially within compositional regions which have been proven conclusively to be sigma forming, serious consideration must be given by specification-making bodies, such as the American Society for Testing Materials and American Iron and Steel Institute, to modifying these specifications in such a way as to reduce or eliminate this potential source of service difficulty. As the authors point out, serious embrittlement is apt to be effected by as little as 5% sigma; the limiting compositions in these specifications, particularly as they are concerned with maximum chromium contents, must be selected carefully.

C. H. SAMANS

Brittle Fracture of Mild Steel*

At the Edinburgh (Scotland) 1951 meeting of the British Association, T. S. Robertson of the British Naval Construction Research Establishment, Rosyth, gave the research results obtained with a new brittle-fracture test for carbon steel plate. As is well known, tests for brittleness mostly follow one main pattern. A notched test piece is pulled or bent until, after some degree of strain, a crack propagates from the notch. The nature of the crack can be changed from tough to brittle by the controlled variation of analysis, speed of testing, size of the test piece, geometry of the notch, heat treatment, and even the temperature at which the test is carried out.

As temperature is one of the more easily controlled variables, other variables are studied by producing a temperature transition curve for each of the variations in

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*Digest of "Brittle Fracture of Mild Steel", by T. S. Robertson, a paper presented to Section B of the British Association Meeting, August 15, 1951, at Edinburgh, Scotland.

Brittle Fracture of Mild Steel

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turn. More generally, it is claimed that temperature transition curves resulting from different forms of tests put the steels tested in the same order of brittleness, but it is admitted that the temperature ranges obtained cannot be applied in practice. The designer is only given an order of merit; no safe stress is quoted, nor is a stress allied to a safe working temperature.

An investigation into the effect of very sharp notches on results of brittleness tests shows that even with a sharp fatigue crack as the notch, local yielding occurs at the root of the crack before brittle fracture propagates through the adjacent, slightly yielded material. The experiment also establishes that, with these sharp fatigue cracks, a sudden loss in strength is experienced as the temperature of test is lowered. This is contrary to experience with standard notched test pieces, but is believed to represent a practical condition in the catastrophic failure of ships where the nominal stress level in way of the fracture has been as low as 11,200 psi. Attention has therefore been directed to the development of a test that will employ as sharp a notch as the material is capable of producing; namely, a propagating brittle crack.

In the method employed, a crack started in the material under conditions of great brittleness, and the resistance to its continued propagation into a zone of increasing toughness is studied in terms of a known stress imposed transversely to the direction of propagation of the crack.

The test piece is 12 in. long by 3 in. wide, and is flame cut from the plate. One end is rounded and a 1-in. diameter hole is drilled centrally in the width near this end so as to leave ¼-in. thickness of metal under the radius. A jeweler's sawcut is made centrally in the width on the side of the hole remote from the radiused end. The test piece is welded into two transverse loading lugs 10 in. wide with the rounded end protruding to one side. The connection between the lugs and the test piece includes a strip of material thinner than the test piece that has been heated to relieve welding stresses and to insure uniform transverse stress in the test piece.

Liquid nitrogen is poured into the hole in the end of the test piece, the remote end being heated by a gas flame. By this means a very uniform temperature gradient from about −112° F. at the notch to about 140° F. at the remote end is obtained. A transverse stress of known value is applied through the loading lugs and the rounded end is given a single sharp blow delivered by a bolt gun.

The shock starts a brittle crack at the notch. Under the influence of the transverse stress the crack propagates into the material through zones of gradually increasing temperature until a temperature is reached at which it stops. The progress of the crack up to this point is at exceedingly high speed; photographic records at 4000 frames per sec. prove too slow to measure it. The material ahead of the crack now yields under the applied transverse load. Sometimes a second crack propagates at high speed into this yielded material.

The general pattern of results is that, at high transverse stress values, the temperature at which arrest of the crack takes place varies only

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Brittle Fracture of Mild Steel

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slightly with reduction of stress. Eventually a stress level is reached at which a sudden drop in arrest temperature is experienced. After this drop, the temperature for arrest again varies little with reduction of transverse stress. In fact, a stress-temperature transition curve has been produced.

In a steel which propagated brittle fracture at about 50° F., the crack was arrested in this test at 68° F. at transverse stresses above and including 16,800 psi., but the arrest temperature fell to −40° F. at a stress of 11,200 psi. The test offers the designer a link with practice in its method and gives him a basis for the design of structures in terms of the temperatures and stresses to be met with in practice. As a confirmation, a single test piece tested at the proving stress will establish the suitability of the material for the job. The test piece is inexpensive to produce and it will be possible to use a very simple form of transverse loading device.

TOM BISHOP

Powder Iron for a Weld Back-Up Material*

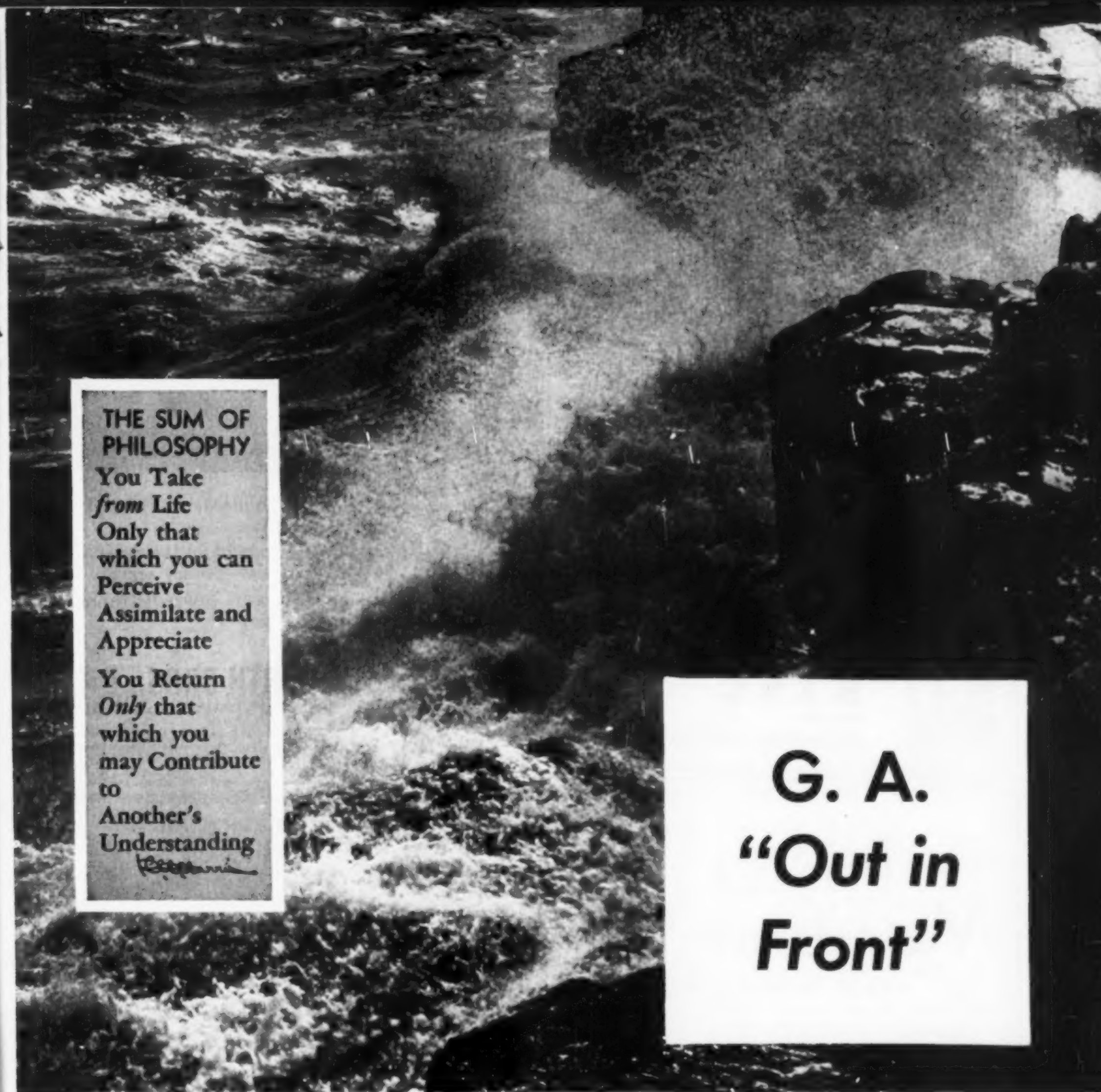
BUTT WELDING OF STEEL PLATES by any of the fusion processes is usually done after the adjoining edges have been chamfered, beveled or otherwise prepared. Such Vee-seams are then assembled or jigged and backed up with iron or copper bar to prevent loss of weld metal on the first pass. Iron or steel back-up bars are ordinarily used if they can be left in place; copper back-up bars if the power side of the weldment must be ground or chiseled out for a finishing pass.

It has been found that powdered iron has definite advantages as a back-up material. To retain the powder in place, it may be finely pressed by hand into a shallow channel formed of thin sheet metal, thus forming the equivalent of a back-up strip 3/16 in. thick by 13/16 in. wide. Alternatively the powder can be compacted under hydraulic pressure at 1200 psi. into a long bar, say ¼ in. thick by 1 in. wide. Such compacts can be used as is, or their strength may be increased by a light sintering. Hand packing of a sheet metal channel is entirely adequate, however, and can be bent to long radius to fit inside a pipe.

Heat conductivity of the powdered iron is lower than that of a copper back-up bar. Warpage is substantially less, for the same reason. The hardness of metal alongside the weld (if made in hardenable steel) is also lower. For example, ⅝-in. plates of 0.25% carbon steel welded with powder iron back-up bar had Brinell hardness of 185 alongside the weld at bottom, 212 at the weld at top, and 300 at the rewelded root layer.

Transverse tests on welds in ½-in. plates, bottom of seam at outside of bend, bent 150° without fracture in either, S.A.E. 1015 or 1025 steels, regardless of whether the bottom of the seam remained as welded or was machined smooth. In 50 tests in bending, surplus weld metal machined off both sides, 49 bent 150° without fracture, the 50th one breaking due to poor fusion.

*Digest of "Iron Powder as Base Material for Weldments", by Dr. H. Hauttmann, director of research and development, United Austrian Iron and Steel Works (VOEST), Linz, Austria, in Voest Yearbook, 1950-1951. Translated by Hubert J. Pessl, chief metallurgist, Lake Erie Engineering Corporation, Buffalo, N. Y.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1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio; Editor, E. E. Thum, 7301 Euclid Ave., Cleveland 3, Ohio; Managing Editor, M. R. Hyslop, 7301 Euclid Ave., Cleveland 3, Ohio; Business Manager, W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.

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E. E. Thum,
Editor.

(Seal)

Sworn to and subscribed before me this 1st day of October, 1952.

Genevieve G. Fitzgerald
Notary Public.

(My commission expires March 26, 1955.)

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